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CONCEPTUALIZATION AND DESIGN

OF A

VARIABLE-GRAVITY RESEARCH FACILITY

PREPARED FOR

ADVANCED SPACE DESIGN PROGRAM

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CENTER FOR AEROSPACE SCIENCES

UNIVERSITY OF NORTH DAKOTA

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UNIVERSITY OF NORTH DAKOTA

CENTER FOR AEROSPACE SCIENCES

VARIABLE-GRAVITY RESEARCH FACILITY

CONCEPT: TO PROVIDE FACILITIES FOR THE STUDY OF THE EFFECTS OF VARIABLE-GRAVITY LEVELS IN REDUCING THE PHYSIOLOGICAL STRESSES UPON THE HUMAN OF LONG-TERM STAY TIME IN ZERO-G.

PARAMETERS: ARTIFICIAL GRAVITY INDUCED BY ROTATION
RANGE 0.1G - 1.0G
UP TO THREE YEARS STAY-TIME
HUMAN EXPERIMENTATION ONLY
USE OF EXISTING MATERIALS & FACILITIES
MINIMUM MODIFICATIONS
SHUTTLE LAUNCH (MINIMUM POSSIBLE)

DESIGNS STUDIED: TWIN-TETHERED TWO MODULE SYSTEM WITH A CENTRAL DESPUN MODULE WITH DOCKING PORT AND WINCH GEAR

RIGID ARM "TUBE" FACILITY USING SHUTTLE EXTERNAL TANKS

MAKE-UP OF STUDY GROUPS: TWO DESIGN TEAMS OF 4 ENGINEERING STUDENTS EACH. ONE TEAM STUDIED WINCH DESIGN OF TETHER SYSTEM, THE OTHER TEAM STUDIED MOVING-FLOOR DESIGN FOR EXTERNAL TANK SYSTEM.

ADDITIONAL 25-MEMBER INTERDISCIPLINARY GROUP (5X5 TEAMS) STUDIED VARIOUS ISSUES INCLUDING DESPUN CENTRAL CAPSULE CONFIGURATION, DOCKING CLEARANCES, EVA REQUIREMENTS, CREW SELECTION, CREW SCHEDULING, FOOD SUPPLY & PREPARATION, WASTE HANDLING, LEISURE USE, BIOMEDICAL ISSUES (BONE & MUSCLE LOSS, SPACE SICKNESS, ETC.), PSYCHO-SOCIAL ISSUES (PRIVACY, SEXUAL ISSUES, ISOLATION, ETC.).

INTERDISCIPLINARY TEAMS COULD CHOOSE EITHER FACILITIES. THEY WERE EXPECTED TO STUDY, DOCUMENT AND RECOMMEND: EQUIPMENT NEEDS, LIVING CONDITIONS, INTERNAL LAYOUTS, POSSIBLE ALTERNATE DESIGNS, POSSIBLE OPERATIONAL PROBLEMS AND FIXES. COMMUNICATIONS WERE MAINTAINED BETWEEN THE ENGINEERING & INTERDISCIPLINARY GROUPS THROUGH T/A, FACULTY MEMBERS AND STUDENT PRESENTATIONS.

METHOD PROVED SUCCESSFUL IN INVOLVING LARGER NUMBERS OF STUDENTS IN UNDERSTANDING THE MULTIFACETED ISSUES OF OUR MOVE INTO SPACE. STUDENT REACTION WAS VERY POSITIVE. MANY ISSUES WERE DEFINED AND DOCUMENTED, SOME TENTATIVE CONCLUSIONS REACHED REGARDING FACILITIES AND EQUIPMENT REQUIREMENTS FOR LONG-TERM, HUMAN STAY-TIME AND EXPERIMENTATION IN SPACE.

INTRODUCTION

David C. Webb and Dick B. Parker

The physiological and other impacts upon humans of long-term stay time in space have received only limited study. The initiation of Space Station, and possible future missions to the Moon, Mars and the asteroid belt, make it imperative that an understanding of these impacts be achieved as rapidly as possible, as well as an understanding of the possible remedial effects of introducing various levels of rotation-induced gravity in space habitats.

The Center for Aerospace Sciences at the University of North Dakota received a grant in September 1986 from the Advanced Space Mission Design Program for initial design work associated with an on-orbit variable-gravity research facility.

A Variable-Gravity Research Facility was proposed as one of the priority recommendations of the National Commission on Space. The members urged that it should be designed and flown at the earliest possible date. The present study is based upon the assumption that it is possible and preferable to design, develop, launch and use such a facility as a part of the initial build-up for the Space Station.

The proposed facility could be on-orbit and in use by 1994, given priority development and fabrication - at a time and cost level impossible to duplicate under other circumstances. This would meet the President's promise of 1984, to have a station on-orbit within a decade, and could have important political advantages for NASA and the nation's space program.

Work at the University of North Dakota

Eight senior-year engineering design students were divided into two teams of four persons for this effort. One was requested to develop a solid structure, the other a tethered system. The first team conceived a major facility utilizing a number of interconnected hydrogen tanks derived from the STS External Tank. They concentrated on the design of the movable floor that would be placed in each tank. The other team chose a two-tethered, two-module facility, using space station modules. They concentrated their design efforts upon the winch system required to alter tether lengths.

In addition to these efforts, a multidisciplinary (MD) undergraduate course, open to all sophomore and above students, was offered for the purpose of conceptualizing and documenting the issues and problem areas that might be met in long-term (up to three years) on-orbit experimentation on human subjects. This three-credit course has been in operation for two semesters. Forty-four students registered for the first semester and twenty-three for the second.

The MD classes could choose either of the proposed facilities (tethered space station modules, or external tanks) as models. They were expected to study, recommend and document equipment requirements, internal lay-outs, and possible alternate design proposals, as well as to develop a list of issues and problem areas that might be met in operation, including possible fixes.

Communications were maintained between the engineering and multidisciplinary groups through faculty members, teaching assistants, and student reports. As student understanding increased regarding some of the real economic, engineering and human factors issues involved in the development and operation of such a facility, it became clear to all that the design of the first engineering team (six interlocked hydrogen tanks with movable flooring) although attractive because it offered the capability of multiple gravity levels within one facility, was too complex and expensive and required too much on-orbit EVA to make it likely that it would be chosen for development. Nonetheless, the engineering students learned much about the design stresses and requirements that will be placed upon any use of the external tank for such a facility, while the MD students learned a lot about real-life cost/usage trade-offs.

As a result, in the second semester it was decided to concentrate MD student attention on the two-tether, two-module design of the second team, with the addition of a third (central) module for docking. A number of issues (detailed below) were examined. This does not mean that the External Tank option is no longer under study, but only the particular concept of it presented by the first team. Next year other ET options may be examined.

Concept, Parameters and Assumptions of Study

The physiological and other impacts upon humans of long-term stay time in space have received only limited study. The initiation of Space Station, and possible future missions to the Moon, Mars and the asteroid belt, make it imperative that an understanding of these impacts be achieved as rapidly as possible, as well as an understanding of the possible remedial effects of introducing various levels of rotation-induced gravity in space habitats.

It was further assumed that the above requirements dictate the use of available materials and designs to the greatest possible extent. To this end, the present study concentrates on two possibilities for a Variable-Gravity Research Facility: The use of Space Station derived modules, or of the shuttle External Tank.

Established Parameters:

Artificial gravity induced by rotation

Range 0.1g - 1.0g

Up to three-year stay-time

Human experimentation

Use of existing materials and facilities where possible

Minimum modifications

Shuttle launch (minimum number possible)

Concepts Studied:

Tethered system with two modules and two tethers with winches to control inter-module separation and thus apparent gravity level.

Rigid arm system with either space station module or external tank.

After the fall semester the decision was made to concentrate on the tethered system.

The issues addressed are identified in the table of contents as chapter titles. Each chapter represents the report of a single or group of students. The first two chapters are the work of the engineering design students. The remaining chapters are the work of students in the multidisciplinary course. As a result, there is some variation in the quality of individual chapters. None the less they present issues (and possible solutions) which must be addressed and settled before a variable-gravity facility can be flown. Not all important issues have been addressed at this time. These issues, plus refinement on some existing topics will be the work of the second year of this project.

Issues Still to be Defined:

Crew size

Crew space per person

Medical equipment required

Facility stability with central core extended

Tether stability, vibration, resonance

Stresses from docking impacts

Power requirements/source/despun?

Tentative Conclusions & Additional Questions:

The issue is what rotation-induced gravity level will be required for maintaining human health while doing longer term work in space and permitting return to earth. Currently we know that people survive well at 1 G, on earth. Currently we know, on limited data, that moon gravity (1/6 G) does not completely overcome the deterioration experienced in 0 G. Currently we know that there is serious deterioration at 0 G.

Most biological functions are log functions and one can reasonably assume that the same is true of the effects of gravity. Three points (gravity levels) between 1/6th and 1G should provide sufficient data to draw biological response curves to gravitational force. This would permit preliminary estimates to be achieved that are fairly close to the gravitation (rotation-induced artificial gravity) levels which are required to maintain human health. These three points could be about 0.63G, 0.40G, and 0.255G to distribute them linearly along a log plot equidistant between 0.16G and 1.0G. The middle value is very close to Martian gravity of 0.39G.

Six months research at these three induced gravity levels would provide substantial data at 4 points on the curve (4th point is 1G), and minimal data at a 5th point, Lunar gravity. (Lunar gravity values will eventually be obtained on the moon and could be left until then if necessary.)

Eighteen months of research thus could provide a preliminary estimate of the rotation-induced gravity level necessary to maintain human health for long periods in space. Long-term exposure to the selected gravity level would be required before great dependency on it could exist. If time permits, the initial v-g facility should be run at one specific gravity level for as long as possible to properly evaluate the effects at that level.

POSSIBLE CONFIGURATIONS

Several designs for making a variable-gravity research facility (v-g) are possible. On examination, it becomes apparent that it would be feasible to construct the variable-gravity research facility before constructing the space station, by using modules which will later be incorporated into the space station. An eighteen month experimental period could provide a preliminary answer to the major issue of long-term survival in space, which otherwise will be put off until after the year 2000. The proposed sequence would cause little or no delay in the space station schedule.

All of the possible designs have the following things in common:

1) they use space station modules which can later be used in the space station.

2) they require minimum modification of these modules for this purpose.

3) they require only one or two additional shuttle loads of equipment for the v-g facility.

The basic configuration is a rotating structure with habitation module(s) at the end(s). Variables in the design include:

1) a) Two or
   b) one end of the structure inhabited?
   The other end could just be a counter weight.

2) a) Tether or
   b) latticework beam structure connection?

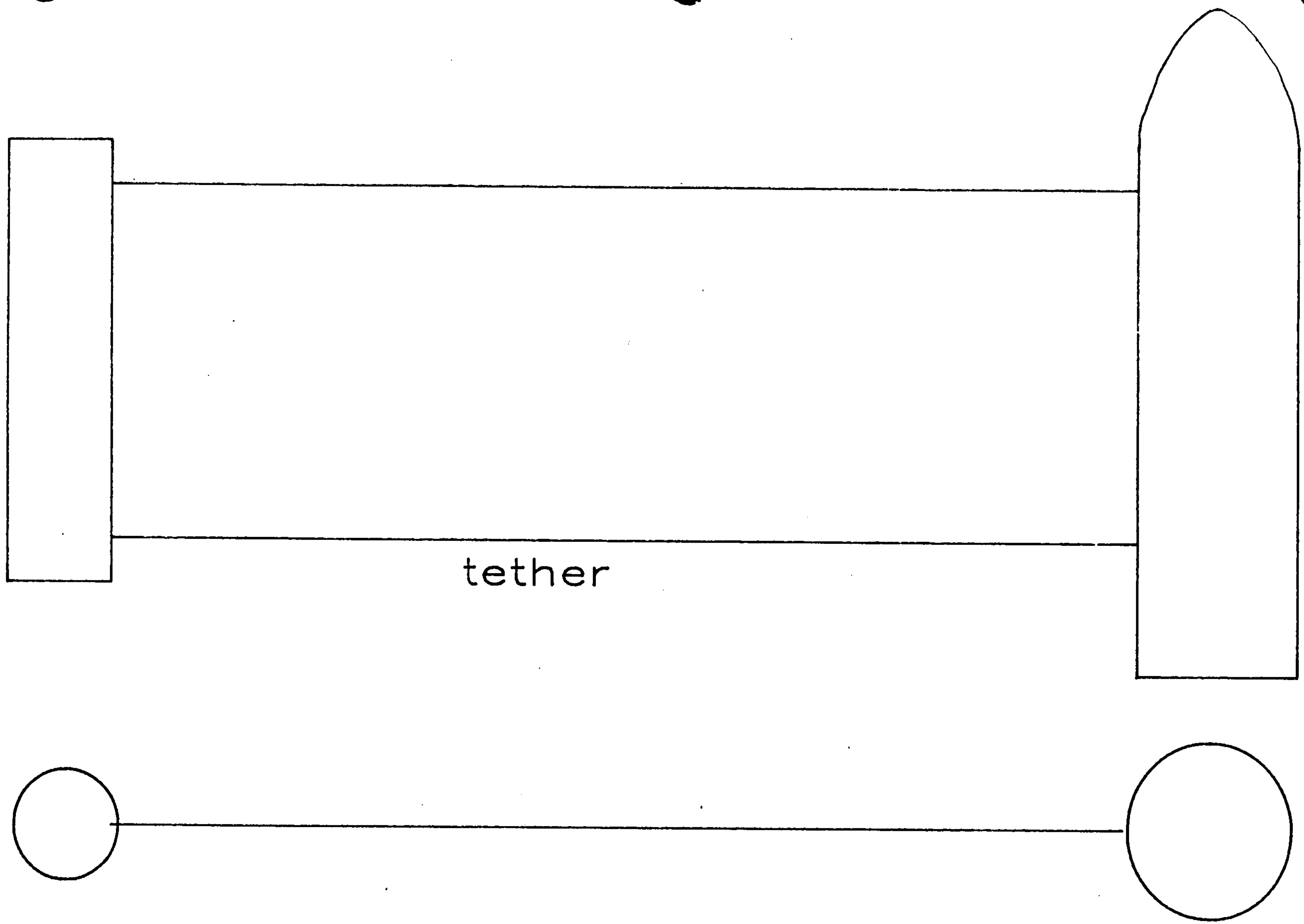
3) a) Absence or
   b) presence of a central, 0-G module which would not be spinning and could serve as a docking point and a 0-G research module.

4) a) One or
   b) two modules at each end of the structure.

Essentially all combinations of the four alternate pairs listed above are possible design configurations.

The simplest configuration, Figure 1, is a single habitation module tethered to an external tank as a counter weight. Different levels of gravity are obtained by varying rotation rate. This facility could be flown on a single shuttle mission.

Figure 2 shows a tethered system with a central (despun) module and elevator. The shuttle would dock at the central module. Four winches will maintain a fixed center of rotation at all times. Various rotation-induced gravity levels are obtained by changing the length of the tethers.



V—Gravity module

Fig. 1

not to scale

External Tank

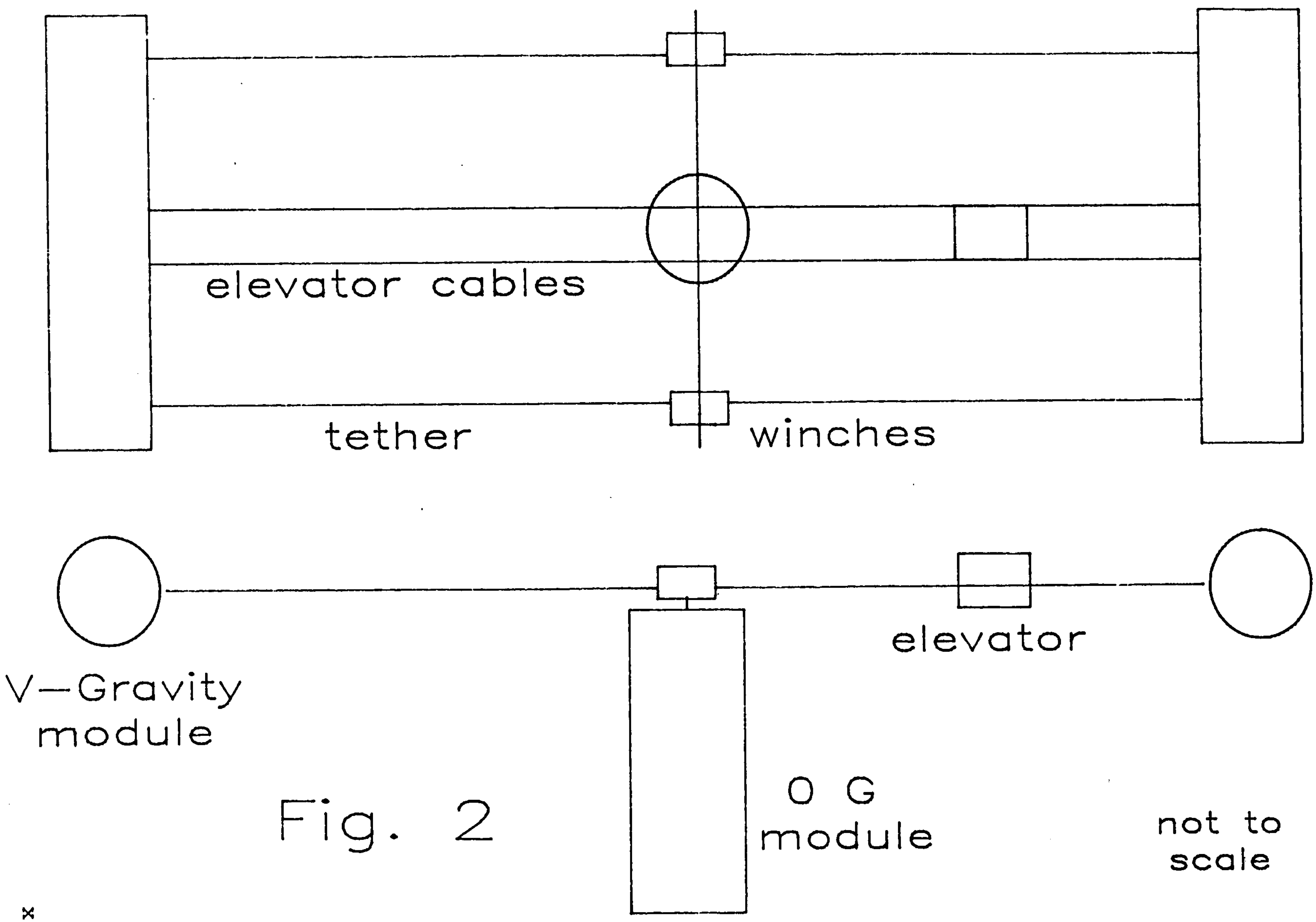

elevator cables
tether
winches
V—Gravity module
elevator
0 G module
not to scale

Fig. 2

Chapter 1

FINAL REPORT

CABLE TETHER SYSTEM

M.E.488

PROJECT 701, ASTRODYN

To: Mr. Dan Ewert

From: Leon Yesel

Ron Johnson

Marlon Hovland

Roger Anderson

Date Submitted: 4/24/87

LETTER OF TRANSMITTAL

TO: Dan Ewert
c/o Mechanical Engineering Dept.
University of North Dakota
Grand Forks, ND 58202

FROM: ASTRODYN

Marlon Hovland
Roger Anderson
Ron Johnson
Leon Yesel

SUBJECT: Tether Retraction Mechanism Package

DATE SUBMITTED: 4/24/87

This report contains the results of Astrodyn's work on the Variable Gravity Research (VGR) facility project. The project was granted by NASA in August 1986. Astrodyn's focus is a winch retraction mechanism utilizing a Kevlar 29 tether.

Marlon Hovland — Marlon Hovland

Roger Anderson — Roger Anderson

Ron Johnson — Ron Johnson

Leon Yesel — Leon Yesel

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ABSTRACT

This report describes a tether retraction mechanism to vary the distance between two modules of a Variable Gravity Research (VGR) facility.

The VGR consists of two manned modules tethered together, with one module containing the retraction mechanism. The modules have a maximum and equal mass of 28,000 kg each. The external dimensions of the modules are 4.57 m in diameter by 18.29 m long. These dimensions are the maximum payload envelope of the space shuttle.

A maximum of 3 RPM, at a minimum module separation of 200 m, yields synthetic gravity of 1 g. The module separation can be increased by deployment of tether, reducing the rpm and the synthetic gravity to a minimum of 0.1 g. This occurs at a module separation of 440 m.

The retraction mechanism consists of two titanium grooved winch drums designed to store 270 m of 0.025 m diameter Kevlar-29 tether. The maximum retraction/deployment rate is 0.50 m per minute, allowing complete retraction in an 8 hour period.

INTRODUCTION

The purpose of the contract between NASA and Astrodyn is to do research towards the development of a variable gravity research facility. Astrodyn's specific focus is the retraction mechanism. This facility will be used to study the effects of long term exposure to reduced gravity.

The specific parameters specified by NASA that Astrodyn must adhere to include:

- the use of a tether between two manned modules
- a synthetic gravity range of from 1 to 0.1 g
- a maximum of 3 rpm to prevent motion sickness
- a minimum module separation of 200 m to prevent coriolis acceleration effects

Astrodyn concluded that the following additional parameters be specified:

- the modules must fit assembled into the space shuttle cargo bay for a minimum number of shuttle launches
- two tethers be employed for safety
- the winches be mounted at extreme ends of the module for stability

These parameters proved to be realistic, and acceptable in this application. The orbit has not yet been determined which prevents Astrodyn from having temperature data from which to specify tolerances.

BUSINESS/MARKETING

This is a NASA project, contracted to Astrodyn, to be used to determine the long range effects of reduced gravity on humans.

This project is financed by NASA. The limits of financial investment were not specified, although we established that only the finest materials and equipment should be employed. Therefore, cost was not a primary factor with respect to design specifications.

NASA has not indicated who will build the retraction mechanism. The estimated cost per winch is $80 689. This does not reflect OEM prices.

Appendix C contains tabulated price information, and estimated manufacturing costs.

TECHNICAL INFORMATION

VARIABLE GRAVITY RESEARCH (VGR) FACILITY:

The VGR facility consists of two manned modules connected by two tethers. One module will contain two winches, at opposite ends of the module, parallel and staggered about the module centerline. These winches are not in a controlled environment (fig 1).

The range of synthetic gravity is from 1 g at 3 rpm and a module separation of 200 meters, to 0.1 g at 0.63 rpm and a module separation of 440 meters. Conservation of angular momentum causes the reduction of rpm. The initiation of rotation is provided by thruster rockets, which are also used to restore rpm lost to friction [1].

Selection of two winch/tether mechanisms:

1) increases the VGR stability over a single tether
2) prevents fatal separation of the modules in case of a tether fracture
3) eliminates the need for a powered tether guide system by assuring a fleet angle of less than 1.5 degrees [2].

Each module has a maximum operational mass of 28 000 kg and external dimensions of 4.57 m in diameter by 18.29 m in length. These dimensions are the largest allowable that can be launched assembled, except for solar panels and antennas, in the space shuttle. The mass figure is based on new projections of the maximum shuttle payload capacity [3].

Our intention was to minimize the number of trips into space and assembly time in space. The external hardware, (solar panels, etc.) will be inside the modules during launching, and attached in space. The only other assembly in space involves the connections of tethers to the module not containing the retraction mechanisms.

The floor space is 37.0 square meters, plus 6.20 square meters in each of the two decompression chambers (fig. 1). These are based on a wall thickness of 0.20 m and a floor width of 2.90 m.

A potential docking system could consist of a ski lift type arrangement running along a tether. This could be fed supplies with the space shuttle's cargo bay arm while at the center of rotation. It could also be used for transportation between modules. Rotation of the VGR system could be maintained during supply transfer.

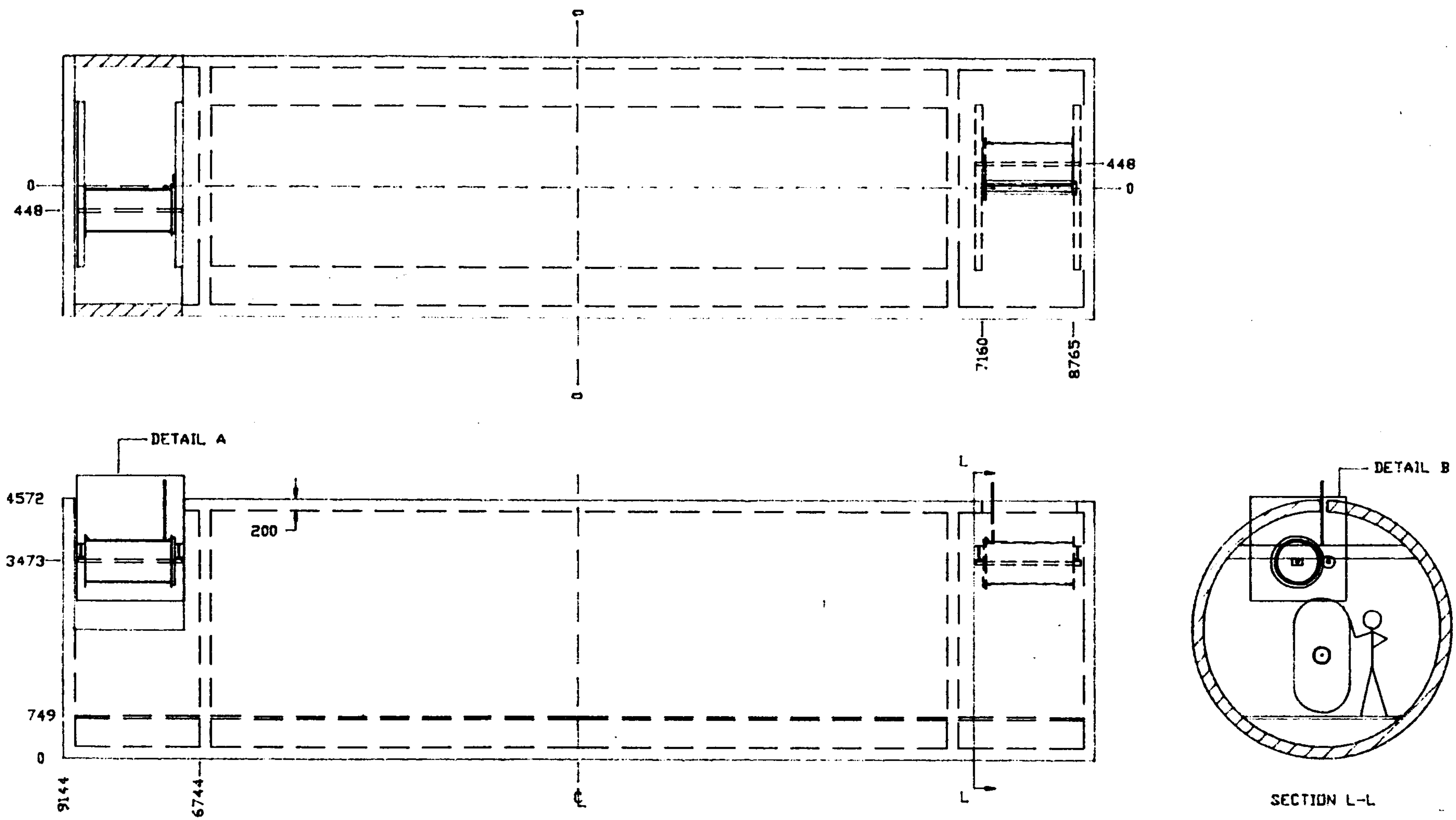


Figure 1 Module Views

TETHER:

The tether material is braided Kevlar 29. The diameter is 0.025 m, plus a 0.00025 m protective Teflon coating. This is a product of DuPont Chemical Company. Information about Kevlar 29 was received from Cortland Cable Co. [4]. A total of 940 meters are required, including the 12 dead wraps on each drum.

Denver Aerospace performed tests and found a tensile strength loss of 31% from 6 months of exposure to hot sunlight [5]. The Teflon coating provides the necessary ultraviolet ray protection, for an expected life of 5 years. This assumes no damage or excessive wear to the jacket or tether.

The force required to initiate the VGR rotation is the use of small thruster rockets. This force as well as the wear on the cable from space debris, requires a tether safety factor of 10 [6]. This also allows the remaining tether to have adequate strength to prevent a fatal module separation if one tether fractures.

There are applications where tethers are used to generate electrical power as they cut through the magnetic field of the earth. This requires tether lengths greater than our application. Therefore, our tethers are not conductive. A benefit of a nonconductive tether is the reduction of electrical polarization of the VGR [5], although, electrical connections are required between the modules to eliminate static charges that disrupt radio transmissions. This is beyond the scope of this design project.

WINCH ASSEMBLY:

The diameter of the drum is 0.750 m, based on the drum to tether diameter ratio of 30 to 1. This ratio was recommended by Cortland Cable Company [4], a supplier of Kevlar 29. The width of the drum is 1.525 m, based on the ability to retract 270 m of tether with a maximum of 4 layers. Three layers is a standard maximum to prevent tether from dropping between the wraps of the previous layer. But, this drum employs grooves developed by the Lebus company [7] which allows 4 layers. The drum has a groove depth of one half the tether diameter (fig. 2).

The material selected for the spiders and drum is Ti-6Al-4V. This alloy exhibits a strength to weight ratio twice that of aluminum, and a coefficient of thermal expansion one third that of aluminum [8]. The spider on the gear end of the drum is 0.007 m thick, while the opposite end is 0.01 m thick. The former can be thinner due to the location of the lock and pinion gear which assume the majority of the load when the tether leaves from that end of the drum. A heat treated version of Ti-6Al-4V was selected for the drum shaft for additional strength. The drum, spiders, and shaft have safety factors of 3.5. To attain this, the drum shaft has a 0.70 m diameter, over its entire length of 1.843 m.

The drum shell thickness is 0.025 m. To ensure the drum meets the required safety factor, ground testing must be performed. This is because of the statically indeterminant nature of drums under external loading.

The spider on the gear end of the drum is welded to the drum on the inside around the circumference. The other spider is welded on both the inside and the outside, the later which is contoured to the shape of the groove. Both spiders are welded to the shaft inside and outside. The spiders each have 5 holes 0.175 meters in diameter which serve as access to the inside of the drum, and for weight reduction.

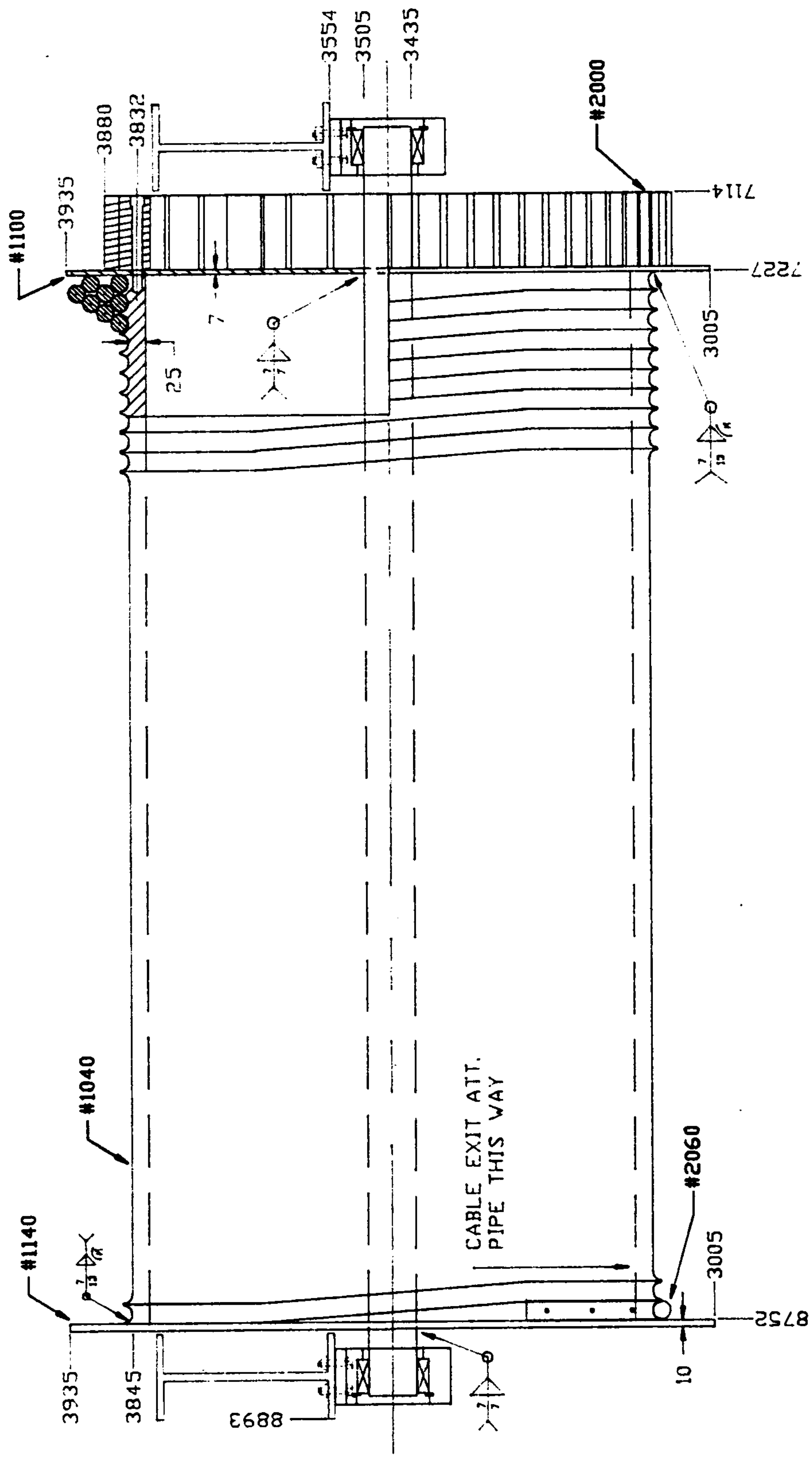


Figure 2 Winch Drum Cutaway

DRIVE GEARS/LOCK ASSEMBLY

The driven gear is a 20 degree, stub involute spur gear, with 64 teeth. It is 0.106 m wide and has a pitch circle diameter of 0.800 m. It is halved for ease of replacement while the winch is under load. Each half is bolted to the end of the drum shell with 22 bolts of 12 mm diameter. The gear itself has a safety factor of 2, while bolts have a safety factor of 3.5. The gear safety factor was reduced for weight considerations and because it is removable for periodic inspection or replacement without stopping VGR rotation.

The drive or pinion gear is 0.103 m wide and has a pitch circle diameter of 0.225 m. It is attached directly to the output shaft of the speed reducer, and has a safety factor of 2.

The drive motor and speed reducer has a brake assembly which brakes through the drive gears. This brake is able to prevent the winch from rotating in the maximum load condition.

In addition, there is a mechanical lock mechanism which locks the winch gear in place (fig 3). This lock will assume the whole braking load during stationary conditions, and will default to the locked position in case of electrical failure, or any time the winch speed exceeds a preset maximum. The safety factor on the lock mechanism is 3.5.

DRIVE MOTOR/SPEED REDUCER ASSEMBLY:

The design of the speed reduction assembly, motor, and control circuits are beyond the scope of Astrodyn's contract. The torque required at the output shaft is 17600 N-m at 0.7 rpm. This allows for the complete retraction of 240 meters in an 8 hour period, at the retraction rate of 0.50 meters per minute.

A safety factor of 2 is recommended, along with a duty cycle that allows for 8 hours of continuous operation. It is required that the assembly include a brake that is able to hold the winch in position during maximum tether load conditions.

All components must be made of material that resists vacuum welding, and can maintain dimensional tolerances over the temperature range of ± 93 degrees C. Also, the motor must require the minimal amount of additional equipment to convert the available power source to a usable form.

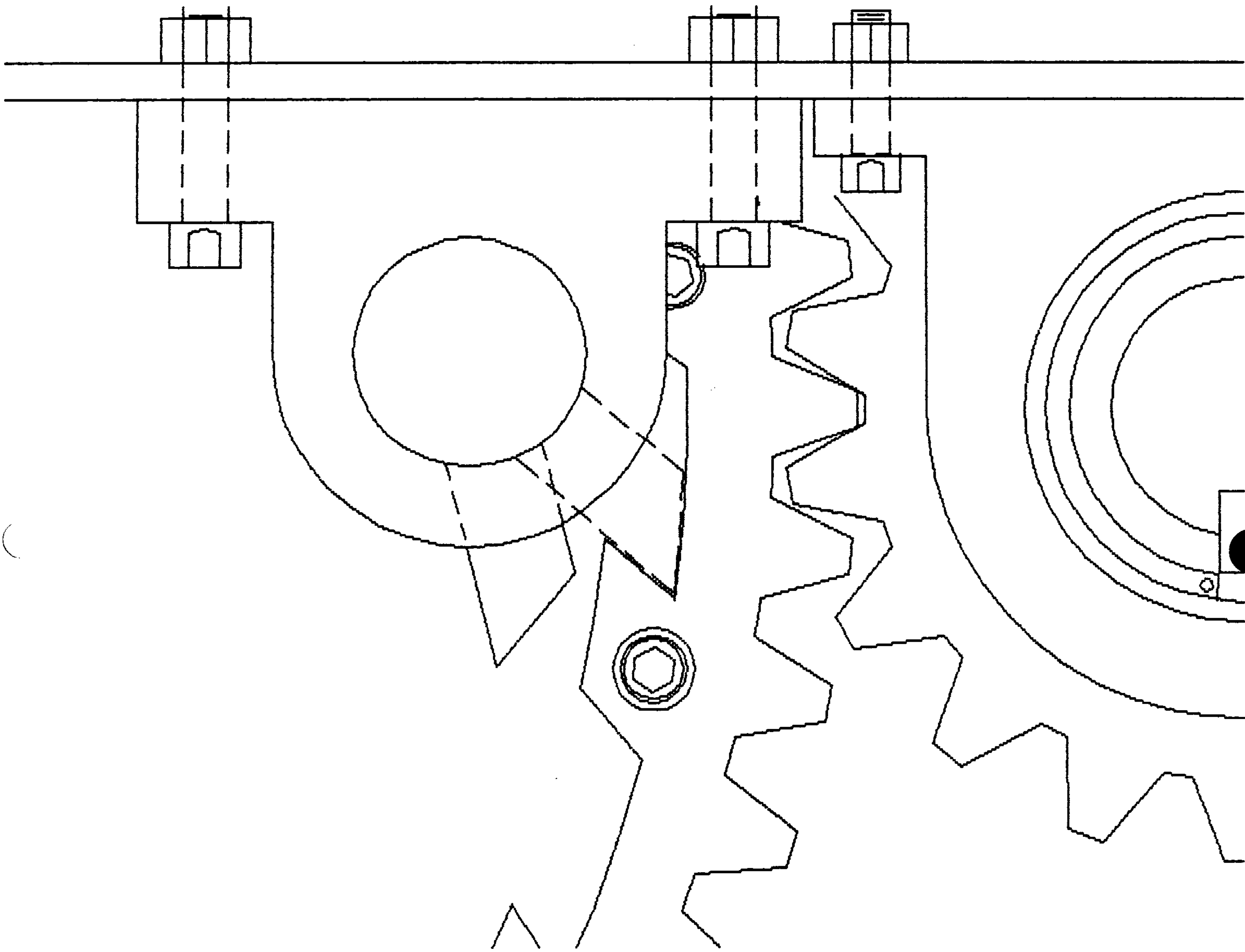


Figure 3 Locking Mechanism

BEARINGS/MOUNTING:

Bearings used in a space environment require dimensional stability over a temperature range of ± 93 degrees C. Because fluid lubricants evaporate in the vacuum of space, teflon or comparable materials are required in the area of contact and wear. Also, the pressure and vacuum tend to cause vacuum welding and the bearings must be of a material proven to resist this tendency.

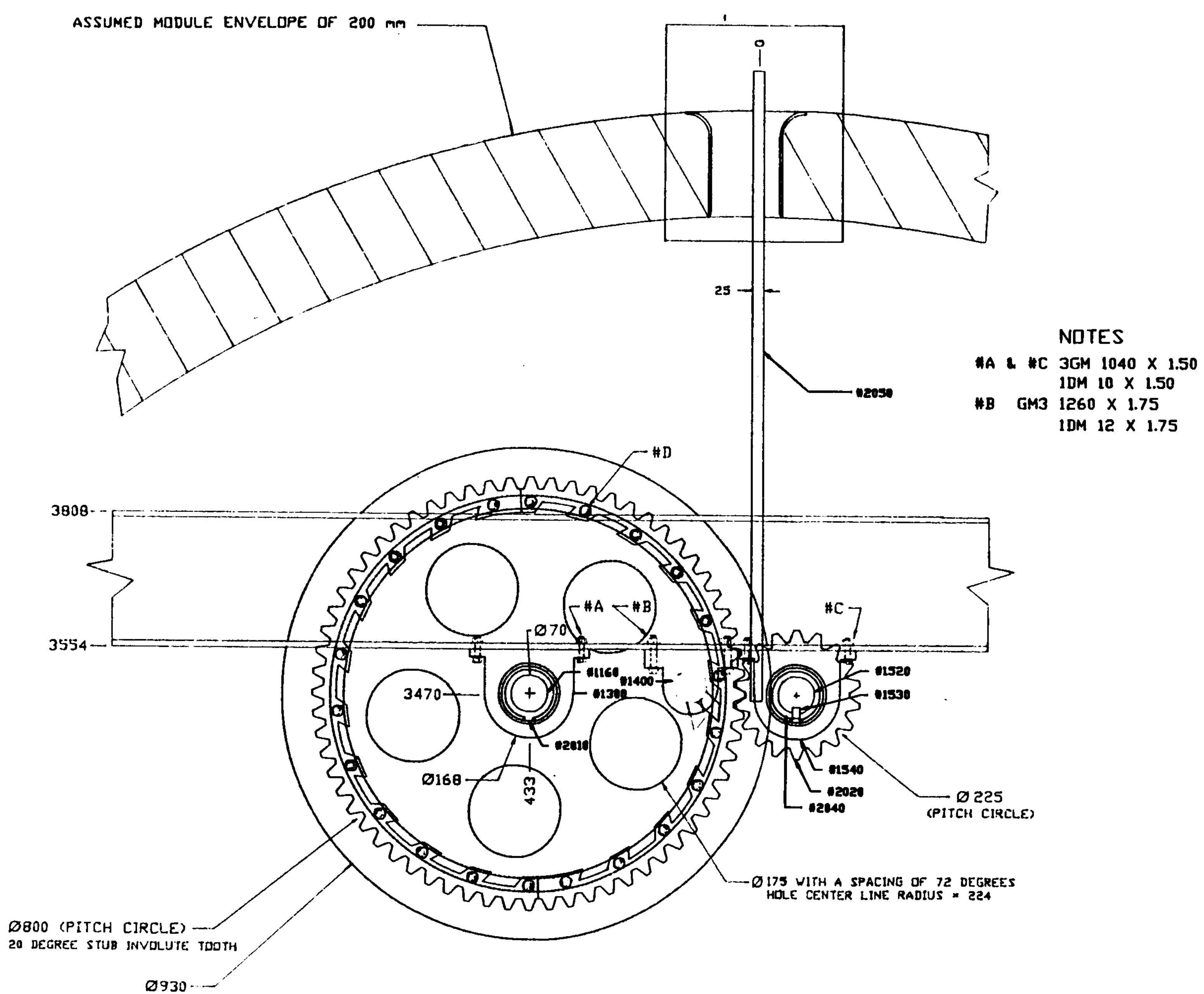
Hard Chromium / PTFE bearings were selected from Elges Bearing Co [9]. They are self-centering, self-lubricating, radial spherical plain bearings. The same bearings and housings are used for the drum shafts and to support the output shafts of the speed reducers. The bearings, housings and bolts have a safety factor of 3.5.

Each bearing housing is made of Ti-6Al-4V. The tolerance between the housing and the shell is a press fit, with a snap ring installed for added safety. The housings are bolted by 4 bolts each of 12 mm diameter to beams running perpendicular to the module length. The mounting is such that the winch load pulls the bearing housings towards the beams, preventing tensile loading of the bolts (fig. 4). All bolts and nuts safety wired, by standards set for general aviation aircraft airworthiness standards, as the method to prevent loosening.

RETRACTION RATES:

This VGR station requires a retraction of 240 meters of tether per winch. The rates were set from considerations of power requirements and time of retraction. A rate of 0.50 meters per minute allows full retraction in an 8 hour period, and requires 2.6 KW total power. The output shaft of the gear reduction must transfer 17590 N-m of torque at 0.7 rpm.

The retraction mechanism control system is not within the scope of Astrodyne's contract.



DETAIL B

Figure 4 Winch Drum End View

CONCLUSIONS

On the basis of Astrodyn's research, a VGR with the stated specifications will fulfill the requirements of achieving synthetic gravity of 0.1 g to 1.0 g. The available living space specified has been discussed with Mr. Charles Walker, and was viewed as realistic and acceptable for the type of space station. Also, it was deemed reasonable to stop rotation of the VGR for docking procedures with the space shuttle.

The orbit has not yet been determined which prevents Astrodyn from having complete temperature data from which to specify tolerances.

Ground testing of the winch drum is required as it is statically indeterminate, when externally loaded.

NOMENCLATURE

Coriolis acceleration: An acceleration which, when added to the acceleration of a object relative to a rotating coordinate system and to its centripetal acceleration, gives the acceleration of the object relative to a fixed coordinate system.

Drum: A horizontal cylinder around which cable is wound in a hoisting mechanism.

Dead wraps: Initial wraps placed on the drum to reduce the load on the attachment anchor. These wraps are never removed when there is tension on the tether.

Fleet angle: In hoisting, the included angle between the tether, in its position of greatest travel across the drum, and a line drawn perpendicular to the drum shaft, passing through the center of the attachment to the opposite module.

Layer: One complete set of wraps the length of the drum.

Spiders: An outside circular disk that contains the tether on the drum.

Wrap: One complete revolution of a cable around a drum.

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[2] Marks' Standard Handbook for Mechanical Engineers. T. Baumeister. 8th ed. McGraw-Hill Publishing Co. New York, New York, 1978.

[3] Personal communication with Charles Walker (shuttle astronaut), Grand Forks, North Dakota, December 1986.

[4] Vendor Literature from Cortland Cable Company, Cortland, New York, 4 November 1986.

[5] Workshop proceedings on applications of Tethers in Space. Final Report: Volume 1. General Research Corporation, 1 December 1983.

[6] Private communication with Paul Penzo, Jet Propulsion Laboratory, Pasadena, California, 10 October 1986.

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[8] Handbook of tables for Applied Engineering Science. Ray E. Bolz and George L. Tuve. 2d ed. CRC Press, Inc.: Boca Raton, Florida, 1981.

[9] Sales Catalog from Elges Bearing Co. 4800 Bielefeld, West Germany, Nov. 1985 edition.

[10] Metals Handbook Desk Edition. Timothy L. Gall. American Society for Metals, Metals Park, Ohio, 1985.

APPENDIX A

SYSTEM SPECIFICATIONS

VGR SPECIFICATIONS:

1) two manned modules connected by two tethers
2) no particular docking capability prescribed
3) stable rotational system
4) synthetic gravity range: 0.1 to 1.0 g
5) synthetic gravity levels altered by the principle of conservation of angular momentum
6) maximum system rotation of 3 rpm
7) maximum module mass 28 000 kg each, in operational form.
8) modules fit inside the cargo bays of the existing space shuttles: Each module's outside diameter is 4.57 m, and is 18.29 m long.
9) one module contains both winches, at opposite ends of the module, parallel and staggered about the module centerline. The retraction system is not in controlled environment (Fig. 2).
10) decompression chambers at the ends of each module are 2.20 m long by 2.82 m wide. Each chamber's floor space is 6.2 sq meters. (These numbers are based on a wall thickness of 0.20 m).
11) available floor space for each of the manned areas of the modules is 37 sq meters (based on wall thickness of 0.20 m)

TETHER SPECIFICATIONS:

1) Braided 0.025 m Kevlar 29 cable
2) A teflon jacket of 0.00025 m thick for ultraviolet ray protection
3) A total of 940 meters is required.
4) 12 dead wraps are used [4].
5) Expected life of 5 years
6) Minimum safety factor of 10.

WINCH ASSEMBLY SPECIFICATIONS:

1) Each drum, spider, gear and shaft is made of titanium alloy Ti-6Al-4V.
2) The drum has Lebus Company developed single step grooves, with a depth of one half the tether diameter.
3) Drum to cable diameter ratio of 30 to 1: drum length of 1.525 m by 0.750 m diameter at the bottom of the drum grooves (Fig. 2).
4) Minimum drum thickness is 0.025 m.
5) The gear end spider thickness is 0.007 m, and the opposite spider is 0.010 m.
6) Shaft diameters are 0.070 m and are 1.843 m long.
7) The tether to winch attachment consists of gluing the tether inside a curved pipe which is bolted into the drum in a winch groove.
8) The drum, spiders and shaft have a safety factor of 3.5.

DRIVE/LOCK SPECIFICATIONS

1) The drive gear is 0.106 m wide, 20 degree stub involute, spur gears. Pitch circle diameter of 0.8 m. The gears are halved and bolted through the spider to the drum shell.
2) The pinion gear is attached to the output shaft of the speed reducer and has a pitch circle diameter of 0.225 m.
3) A mechanical lock assumes the whole braking load when the drum is not rotating, and defaults to the locked position in case of power failure or if the drum exceeds a preset maximum rpm.
4) The gear has a safety factor of 2, while the bolts and lock components have a safety factor of 3.5.

DRIVE MOTOR AND SPEED REDUCER SPECIFICATIONS

1) The 0.07 m diameter output shaft must provide 17600 N-m of torque at 0.7 rpm.
2) The motor and reducer assembly shall include a brake assembly able to hold the winch in position through the speed reducer.
3) A minimum safety factor of 2
4) A duty cycle which allows continuous retraction for the entire 8 hour period
5) The components must be able to withstand the temperature extremes of an uncontrolled environment.
6) The motor must require the minimum amount of equipment to convert the available power.

BEARING/MOUNTING SPECIFICATIONS

1) All bearings must be self lubricating.
2) Dimensional tolerance must be stable for a temperature range of $\pm$ 93 degrees C.
3) A minimum safety factor of 3.5 for the bearings, housings and bolts
4) Mounting must be such as to not subject the bolts to tensile loads.
5) All bolt heads and nuts will be drilled and safety wired as prescribed by aircraft airworthiness standards.
6) The bearing and housings for the drum shaft will be the same as those used to support the output shaft of the speed reducer.

APPENDIX B

MATERIAL SELECTION

WINCH COMPONENTS:

The titanium alloy Ti-6Al-4V was chosen for the winch components because of its proven excellence in aerospace applications [10]. Of all the titanium alloys, Ti-6Al-4V is by far the most commonly used because it offers the best balance of:

- strength
- ductility
- temperature resistance
- corrosion resistance

Compared to aluminum alloys, titanium provides a much greater temperature resistance, and a doubled strength to weight ratio. Its thermal expansion coefficient is one third that of aluminum [8].

TETHER:

Braided Kevlar 29 tether was selected from studies of tests performed by Denver Aerospace for use in similar situations. They found it to be, for their own use, superior to all other tether materials currently available, and highly recommended it to Astrodyn for this application. Technical information was obtained from Cortland Cable Company.

The benefits of Kevlar 29 include:

- strength to weight ratio 5 times that of steel
- three times stronger than Nylon and Polyester per cross sectional area
- a low coefficient of expansion at -1.1 * 10^-6 per degree Fahrenheit

APPENDIX C

COST ANALYSIS

Approximate Raw Material Costs per winch

Part	Dimensions (m)	Weight (kg)	Cost ($)
Spider 1	0.007 x 0.94 x 0.94	27.9	2 008
Spider 2	0.010 x 0.94 x 0.94	39.8	2 844
Shaft	0.076 dia. x 2.03	41.1	2 502
Drum	0.045 x 1.55 x 2.40	745.7	32 900
Lock Shaft	0.076 dia. x 0.23	7.7	286
Pillow Blocks (4)	0.61 x 0.10 x 0.20	122.7	3 468
Miscellaneous			166
		Sub total	$44 174

Purchased Part Costs per Winch

Part	Cost ($)
Driven Gear	2 500
Drive Gear	1 000
Bearings (3)	750
Tether	23 440
Bolts/Nuts	1 520
Miscellaneous	625
Sub Total	$29 835

Labor and Overhead

Total	6 680

TOTAL COST FOR ONE WINCH ASSEMBLY	$ 80 689
TOTAL COST FOR TWO WINCH ASSEMBLIES	$ 161 378

The complete breakdown of the cost analysis is attached on the following pages. The corresponding parts list is found in Appendix D.

1

UND-ME422

PRICE LIST

2 NO EXTENDED QTY? PAGE 1 OF 3

4-1-8

PROJECT NAME NASA CABLE TETHER SYSTEM	PROJECT NUMBER 701
PARENT NAME WINCH	15/HR 25/HR PARENT NUMBER 101

LINE	PART NUMBER	DIRECT MATERIAL	TIME (HOURS)	DIRECT LABOR	OVERHEAD	TOTAL
1 2	1000	Insert Qty	24	360	600	960
3 4	1020		16	240	400	640
5 6	1040		48	720	1200	1920
7 8	1080	32900				32900
9 10	1100		4	60	100	160
11 12	1120	2008				2008
13 14	1140		4.5	67.5	112.5	180
15 16	1160	2844				2844
17 18	1180		2	30	50	80
19 20	1200	2502				2502
21 22	1220	2500				2500
23 24	3GM12120	660				660
25 26	1260		1	15	25	40
27 28	1280	500				500
29 30	7JM78	15				15
31 32	1300		24	360	600	960
33 34	1320	904				904
35 36	1340	23440				23440
37 38						
39 40						
41 42						
43 44						
45 46						
					SUB-TOTAL	73213

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PRICE LIST

PROJECT NAME NASA CABLE TETHER SYSTEM	PROJECT NUMBER 701
PARENT NAME WINCH	PARENT NUMBER 101

PART NUMBER	DIRECT MATERIAL	TIME (HOURS)	DIRECT LABOR	OVERHEAD	TOTAL
1360		2	30	50	80
1380	550				550
2440		1	15	25	40
2480		1	15	25	40
2510	30				30
2460		0.5	7.5	12.5	20
2500		1	15	25	40
2520	30				30
1390		1	15	25	40
1400		1	15	25	40
1215	286				286
1410		1	15	25	40
2530	70				70
1420		16	240	400	640
1440	1660				1660
3GM1090	20				20
1480		5	75	125	200
1500	36				36

SUB-TOTAL 3862

UND-ME422

PRICE LIST

PROJECT NAME NASA CABLE TETHER SYSTEM	PROJECT NUMBER 701
PARENT NAME WINCH	PARENT NUMBER 101

LINE	PART NUMBER	DIRECT MATERIAL	TIME (HOURS)	DIRECT LABOR	OVERHEAD	TOTAL
1 2	3GM820	120				120
3 4	1DM8	40				40
5 6	3GM616	60				60
7 8	1520		2	30	50	80
9 10	1540	1000				1000
11 12	1300		12	180	300	480
13 14	1320	904				904
15 16	1280	250				250
17 18	1700	40				40
19 20	3GM1050	360				360
21 22	3GM1230	120				120
23 24	1DM10	120				120
25 26	1DM12	40				40
27 28						
29 30						
31 32						
33 34						
35 36						
37 38						
39 40						
41 42						
43 14						
45 46					SUB TOTAL	3614
					TOTAL	80689

APPENDIX D

PARTS LIST

PROJECT NAME/NUMBER NASA CABLE TETHER SYSTEM/701

REVISION PARENT NAME WINCH

PARENT NUMBER 101

LINE	FORM	PART NUMBER	U/I	QTY.	PART NAME 1 2 3 4 5 6	REV
1	A	1000	EA	2	WINCH ASSEMBLY	
2	B	1020	EA	1	DRUM ASSEMBLY	
3	B	1040	EA	1	DRUM	
4	A	1080	Kg	436	PL - 40mm Ti 6Al 4V	
5	B	1100	EA	1	DISK	
6	A	1120	Kg	33	SH - 7mm Ti 6Al 4V	
7	B	1140	EA	1	DISK	
8	A	1160	Kg	47	SH - 10mm Ti 6Al 4V	
9	A	1180	EA	1	SHAFT, DRUM	
10	A	1200	Kg	35	SFT - 70mm Ti 6Al 4V	
11	B	1220	EA	1	GEAR, SPLIT	
12	A	3GM12120	EA	22	HX HD CAP SCREW	
13	A	1260	EA	2	MOUNT ASSEMBLY	
14	A	1280	EA	1	BEARING MAIN	
15	A	7JM78	EA	1	SNAP RING	
16	B	1300	EA	1	PILLOW BLOCK	
17	A	1320	Kg	13	PL - 82mm Ti 6Al 4V	
18	A	1340	m	470	CABLE - 25mm dia. (Kevlar 29)	

PROJECT NAME/NUMBER NASA CABLE TETHER SYSTEM/701

REVISION PARENT NAME WINCH
PARENT NUMBER 101

LINE	FORM	PART NUMBER	U/I	QTY.	PART NAME 1 2 3 4 5 6	REV
19	B	1360	EA	1	LOCK ASSEMBLY	
20	A	1380	EA	1	SOLENOID, DC	
21	B	2440	EA	1	BRACKET WELDMENT	
22	A	2480	EA	1	BOTTOM MOUNT	
23	A	2510	Kg	0.5	SH - 7mm Ti 6Al 4V	
24	A	2460	EA	1	TOP MOUNT	
25	A	2500	EA	1	BLANK	
26	A	2520	Kg	0.5	SH - 7mm Ti 6Al 4V	
27	B	1390	EA	1	WELDMENT, LOCK	
28	B	1400	EA	1	SHAFT, LOCK	
29	A	1215	Kg	4	SFT - 62mm Ti 6Al 4V	
30	A	1410	EA	1	BAR, LOCK	
31	A	2530	Kg	1	PL - 26mm Ti 6Al 4V	
32	B	1420	EA	1	PILLOW BLOCK	
33	A	1440	Kg	22	RECT - 125 x 168mm Ti 6Al 4V	
34	A	3GM1090	EA	1	ACTIVATION ARM	
35	A	1480	EA	1	SOLENOID YOKE	
36	A	1500	Kg	0.5	RECT - 28 x 19mm Ti 6Al 4V	

PROJECT NAME/NUMBER   NASA CABLE TETHER SYSTEM/701

REVISION   PARENT NAME   WINCH
PARENT NUMBER   101

LINE	FORM	PART NUMBER	U/I	QTY.	PART NAME 1 2 3 4 5 6	REV
37	A	3GM820	EA	4	HX HD CAP SCREW	
38	A	1DM8	EA	4	NUT	
39	A	3GM616	EA	2	HX HD CAP SCREW	
40	A	1520	EA	1	DRIVE ASSEMBLY	
41	B	1540	EA	1	DRIVE GEAR	
42	B	1300	EA	1	PILLOW BLOCK	
43	A	1320	Kg	13	PL - 82mm Ti 6Al 4V	
44	A	1280	EA	1	BEARING MAIN	
45	A	1700	EA	1	ANCHOR	
46	A	3GM1050	EA	12	HX HD CAP SCREW	
47	A	3GM1230	EA	4	HX HD CAP SCREW	
48	A	1DM10	EA	12	NUT	
49	A	1DM12	EA	4	NUT	

Chapter 2

TUBE TETHER VARIABLE GRAVITY SYSTEM

M.E. 488

Team 702

University of North Dakota, Grand Forks, N.D.

By: Kevin Christianson
Roger Hunter
Mark Love
Joel Pfliger

TO: Dan Ewert

FROM: Team 702, Tube Tethered Variable Gravity Research Space Station.

SUBJECT: Final Report

Attached is the final report for the Tube Tethered Variable Gravity Space Station. This report contains information on the Tube Tethered Variable Gravity Research Space Station designed by Team 702.

SINCERELY,

Joel Pfliger

JOEL PFLIGER
(Current team leader)

DATE: 4-24-87

TABLE OF CONTENTS

LIST OF FIGURES

1.0 Abstract

This report presents the results of a variable gravity research space station design. The report provides a market analysis, design description, and explains the advantages and disadvantages of using the Space Shuttle External tanks for the station.

The space station is constructed from intertank and hydrogen tank sections from the Space Shuttle's External Tank. These sections are connected in space to form a tube. The space station rotates around its longitudinal center to produce the simulated gravity. A floor is placed in each hydrogen tank and by changing its radial position, the simulated gravity is varied. The floor travels on tracks attached to the hydrogen tanks inner walls and is driven by electric motors.

Glenda's produced

2.0 Mission statement

The mission of team 702 is to design a variable length tube tether arrangement for a low earth orbit, variable gravity research space station. The design will include a description of the tube tether and its corresponding extension/retraction mechanism. The final product of team 702 will be a set of detailed drawings and a nonoperating model of the tube tether and extension/retraction mechanism.

3.0 Results/Conclusions/Recommendations

The space station provides simulated gravity from .1 to 1 g, excluding gravity levels between .307g and .379g and gravity levels between .616g and .691g . A control environment is provided where the gravity level is 1+/- 0.065g. This design meets the requirements for a variable gravity research station, but the amount of work required to assemble it in space is a disadvantage.

We recommend that this design be continued with emphasis on simplifying the construction process required in space. We also recommend that a 1/10 scale model of the station be tested in space to determine its stability. Placing the additional components within the hydrogen tank before launch may have an effect on the overall performance of the space shuttle during launch. An analysis is recommended to determine the degree of this effect.

The estimated cost of this project is $79,000.00 in 1987 dollars, with an uncertainty of +/- $10,000.

Due to the special nature of this project. The direct labor rate and overhead cost were not included. The total number of hours for fabrication was estimated to be $1294.54.

3.1 Design concept advantages and disadvantages.

Advantages

- Provides variable gravity between .1 and 1 g.
- Uses existing Space Shuttle External tanks as primary components.
- Provides an earth gravity environment as a control environment for variable gravity experiments.
- Allows experimentation at up to six gravity levels simultaneously.
- Has separate compartments for safety.
- Provides 2211.6 square feet of laboratory floor space.
- Allows for docking without interrupting experiments.

Disadvantages

- Excessive EVA required for assembly.
- Mission profile to carry tanks to orbit not yet validated.

4.0 Background

The need for the space station arises from the harmful physiological effects on people living in zero gravity conditions for extended periods of time in space. For example, after eight months in space, Soviet cosmonauts were so weak they could not walk for five days and so uncoordinated they could not walk a straight line. Their hearts were too weak to supply blood to their brains when they stood and their bones had undergone decalcification which would make them dangerously brittle after a longer journey. Therefore man can not endure more than eight months in zero gravity and do useful work soon after he returns to a gravity environment.

This raises the question: Why would men want to be in zero gravity for eight or more months? The often mentioned "need for man to explore the unknown" is debatable. The bottom line is that man will go on long space journeys to exploit the vast material resources on Mars, in the asteroid belt and beyond. It is not economically feasible to exploit those resources now, but a combination of a growing population on earth and diminishing availability of materials already on earth will eventually make it so. When it does, astronauts will be on space journeys ranging from eight months for a trip to Mars, to over a year for a trip to the asteroid belt.

Because of the previously mentioned effects, astronauts will require some degree of gravity. The gravity required is expected to be less than the gravity on earth but no one knows how much less. It is also desirable to determine if man can live on the moon, which is one-sixth the gravity on earth, or Mars, which is one-third the earth's gravity, for extended periods of time.

5.0 Market Analysis

To answer these physiological questions, NASA needs a variable artificial gravity research station. At this time there is only a need for one research station and it is scheduled to be deployed in the year 2003.

Blade Aerospace's bid provided $**** for completion of the variable gravity mechanism. Costs for the project have been estimated at $79000.00 with a standard 15% profit margin.

Production of the research station will be subcontracted after Blade Aerospace completes design work on the variable gravity mechanism. Final distribution of the system will consist of delivery to NASA's Kennedy Space Center in Florida.

6.0 Coriolis Effect

The use of rotation to produce centripetal acceleration as a substitute for gravity has undesirable physiological effects. They are caused by coriolis accelerations sensed by a person moving inside the rotating space station.

Coriolis accelerations cause motion sickness because of their effect on balance mechanisms of the inner ear. There are four conditions under which coriolis accelerations occur:

1) moving along a radius drawn from the center of rotation,

2) moving tangential to the rotation,

3) "nodding" the head out of the plane of rotation, and

4) "tipping" the head from side to side.

Coriolis acceleration is a function of the rate of rotation. According to the Report of the National Commission on Space, allowable rotation rates from 1 to 10 revolutions per minute will probably be acceptable. Earth simulations of a rotating space station show that most persons are not affected by rotation rates up to 3 RPM, therefore the Variable Gravity Research Station has been sized using 3 RPM as the design rotational speed.

7.0 Tube Description

7.1 General description

The tube is assembled in space from Space Shuttle ET components already in orbit. Six intertanks, six hydrogen tanks and two Aft Manned Compartments (AMC) are connected in series as shown in figure 1 on page 13.

The tube has a fixed laboratory at each end. These laboratories are located in the AMC's which are attached to the external tank prior to launch. This concept is described in the "Space Shuttle External Tank Habitability Study" done by Space Habitation Design Associates. These laboratories are at a 1 +/- 0.065 g environment to act as a control environment to the reduced gravity experiments. All large mass items such as computers, heating and ventilating equipment, and storage will be placed in these fixed laboratories.

The tube rotates with a constant angular momentum while the angular velocity varies slightly between 2.90 RPM and 3.10 RPM due to floor movement.

Our design leaves room for a despun docking port at the center of rotation. Docking is feasible at that location, but beyond the scope of our design mission.

7.2 Liquid Hydrogen tank connection.

The structural connection between the liquid hydrogen tanks uses the existing intertank without modification. The strength built into the intertank, based on loads imposed during launch, provides a safety factor of approximately 12. Use of the intertank will also eliminate the need to carry additional structural connections into space.

The liquid hydrogen tank must be modified by the manufacturer to allow the end to end connection. This modification consists of adding a flange at the hydrogen tank's aft end to match the flange at the forward end of the intertank.

At the hub, two intertank thrust panels are bolted end to end on opposite sides of the tube. The other panels are removed to provide an opening for a Space Shuttle docking tube. Figure 2 on page 14 shows the structural connection at the hub.

7.3 Intertank access tube

Access between the tanks is through a 36 inch diameter aluminum tube bolted to the manhole fittings using the existing bolt hole pattern as shown in figure 3 on page 15. The location of the aft manhole on the liquid hydrogen tank must be changed by the ET manufacturer so it aligns with the forward manhole. Manhole alignment allows for an elevator to be incorporated in the station design.

8.0 Gravity varying mechanism

8.1 General description

A moveable floor is placed in each hydrogen tank. To vary the gravity environment of the subjects, the distance from the floor to the center of rotation is changed. Figure 4 on page 16 shows the floor in the hydrogen tank. The floor structure is placed in the external tank during hydrogen tank assembly and temporarily secured. Once in orbit, the tank is purged of residual fuel, the floor structure is detached from its mounts and a one inch aluminum grate decking attached. Four drive units move the floor along a gear-track system. The drive units are electrically powered and controlled by accelerometers to maintain a constant gravity level.

Due to the geometry of the hydrogen tank ends and the gap between hydrogen tanks, some gravity levels can not be obtained unless the angular momentum is altered. It is assumed that not all gravity levels will be needed. The gravity levels of interest, (1/3g for the moon, and 1/6g for mars), are located within the hydrogen tanks cylindrical portion.

8.2 Floor Structure

Figure 5 on page 17 shows the aluminum I-beam floor structure. Floor drives are attached to the floor where the ends of the main floor beams connect. The smaller I-beams provide support for the decking. All I-beam connections are weldments.

8.3 Floor Track Design

Four equally spaced floor tracks are attached to the hydrogen tank's major ring frames during hydrogen tank assembly. Figure 6 on page 18 shows the floor track. Each floor track consists of a rack with two guideways on its rear portion. The rack is engaged by the floor drive's spur gear. 1.5 inch wheels following on the guideways hold the spur gear in engagement.

8.4 Floor Drive

Each floor is moved by four electric gear drive systems. The floor drive is shown in figure 6 on page 18. The worm gear reducer provides a 150 to 1 reduction and drives a 4 inch spur gear. Since a worm gear drive system can not be back driven, no other securing device is needed.

Table of Nomenclature

AMC	Aft Manned Compartment
ET	External Tank
EVA	Extra Vehicular Activity
NASA	National Aeronautics and Space Administration

References

1) "The Report of the National Commission on Space", 1986

2) "System Definition Handbook, Space Shuttle External Tank"; Martin Marietta.

3) "Space Shuttle External Tank, Layout Drawings Volume II"; Martin Marietta.

4) "Space Shuttle External Tank Habitability Study"; Space Habitation Design Associates.

APPENDIX A

Figures

Overall Length - 667 ft.

RPM - 3.01

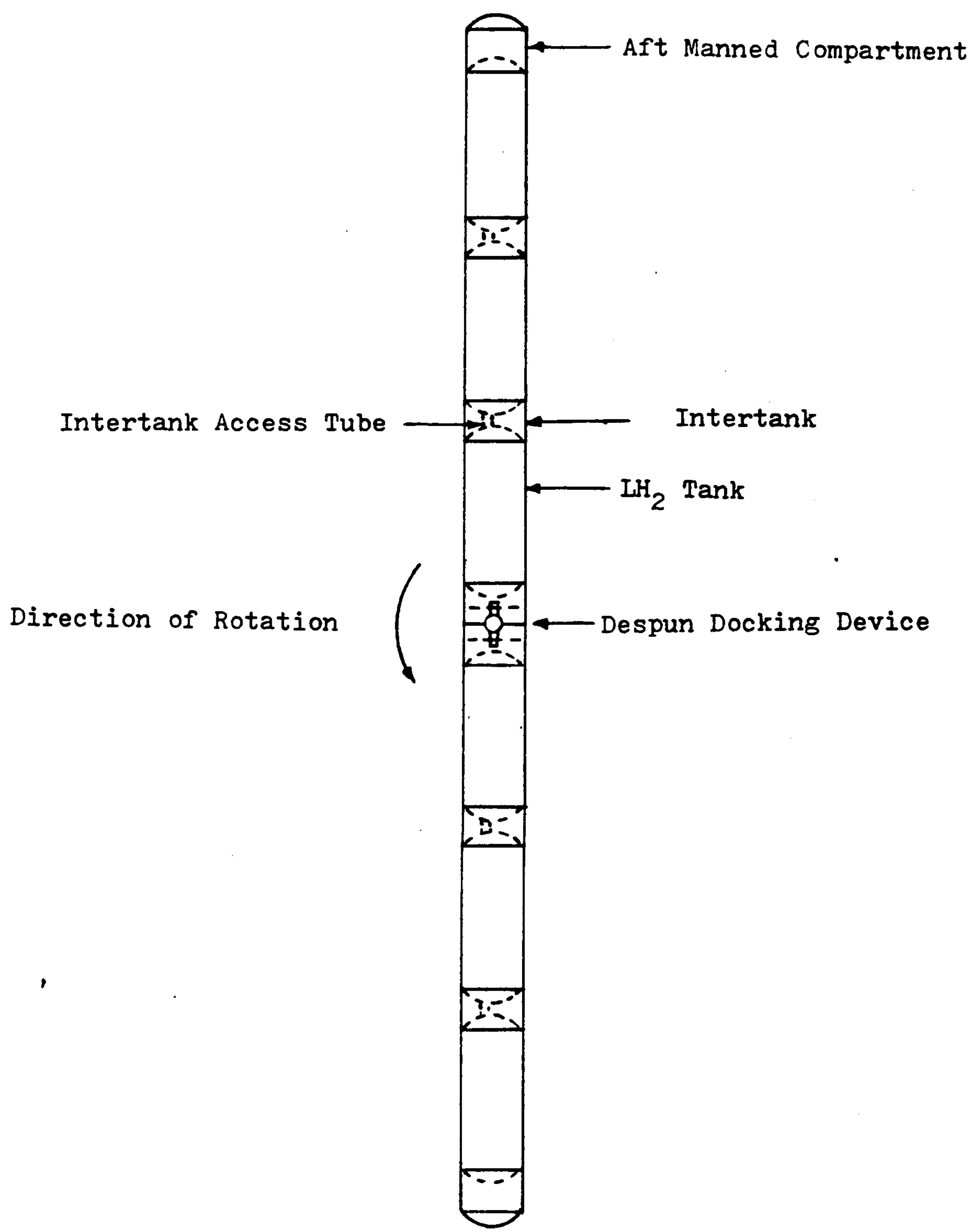

Fig. 1 Tube Concept

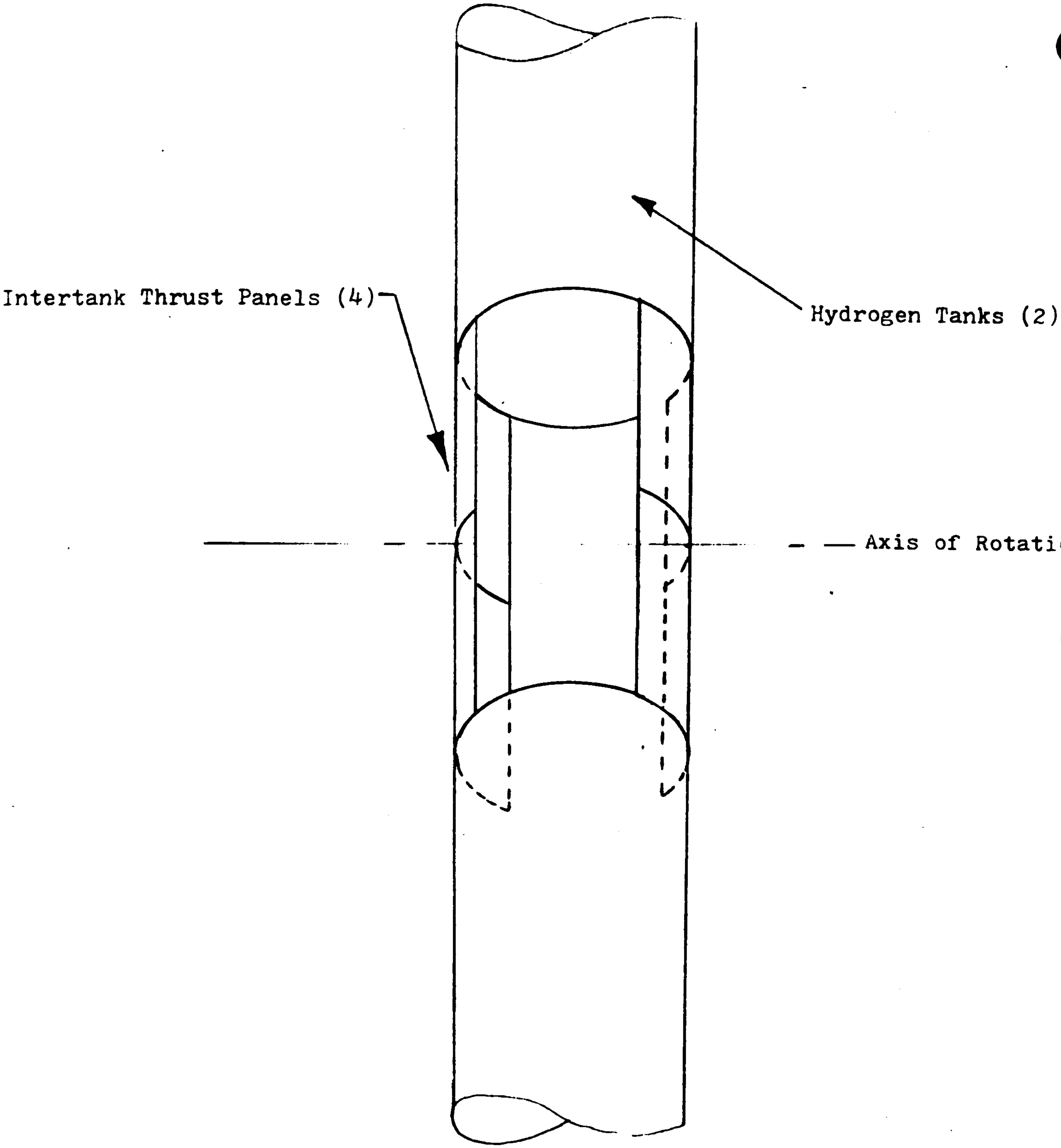

Fig. 2 Hub Structural Connection

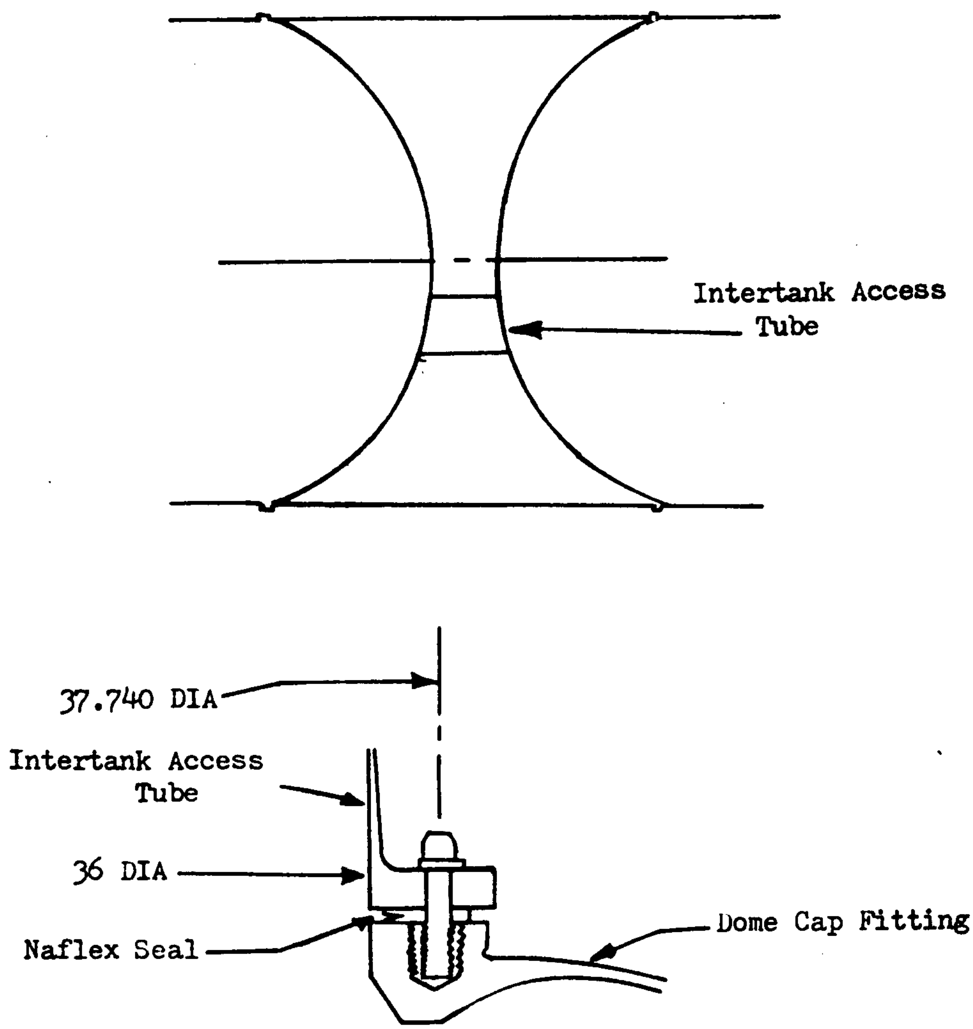

Fig. 3 : Intertank Access Tube Attachment to Existing Manhole Flange

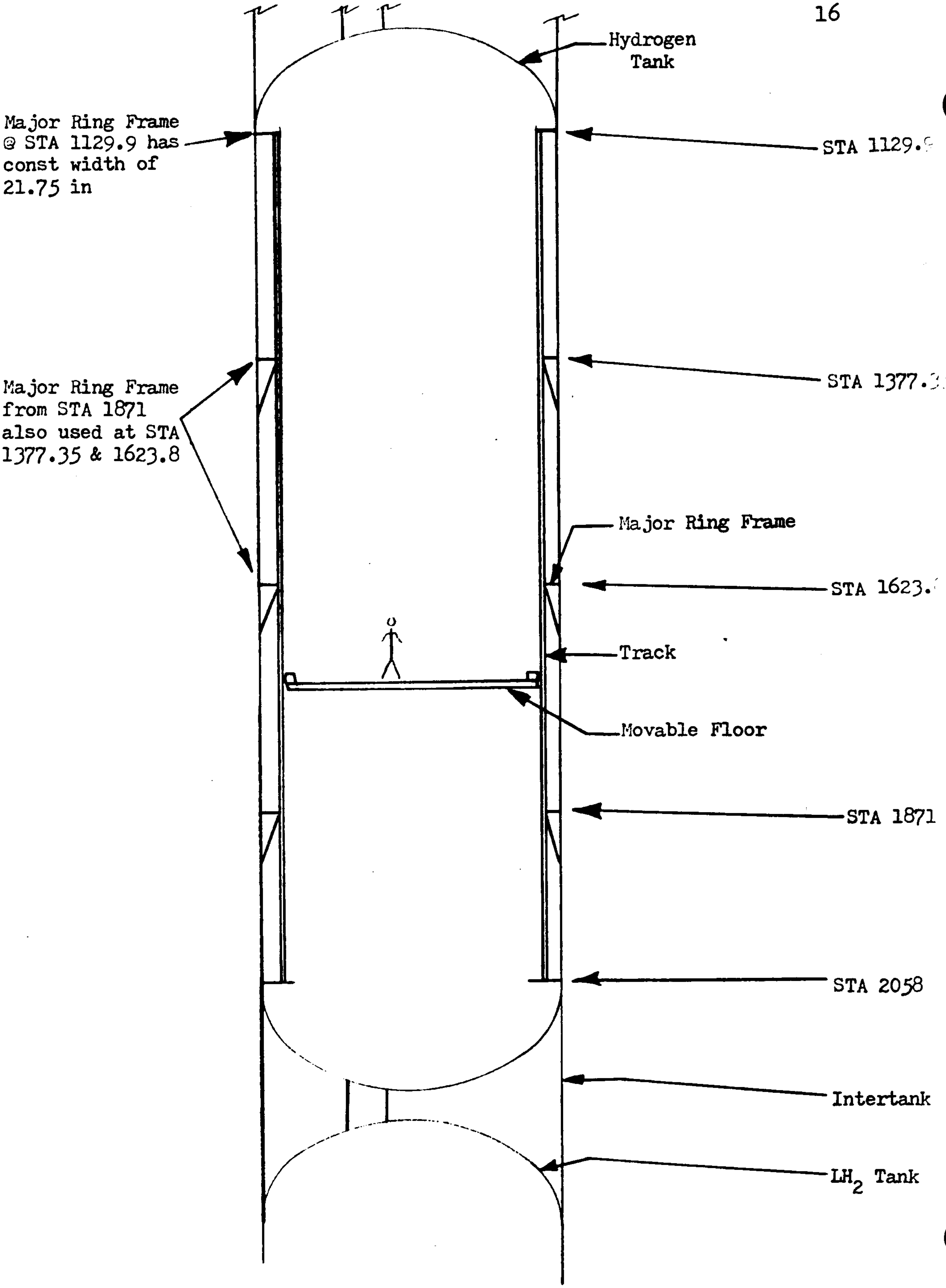

Fig. 4: Radially Variable Floor

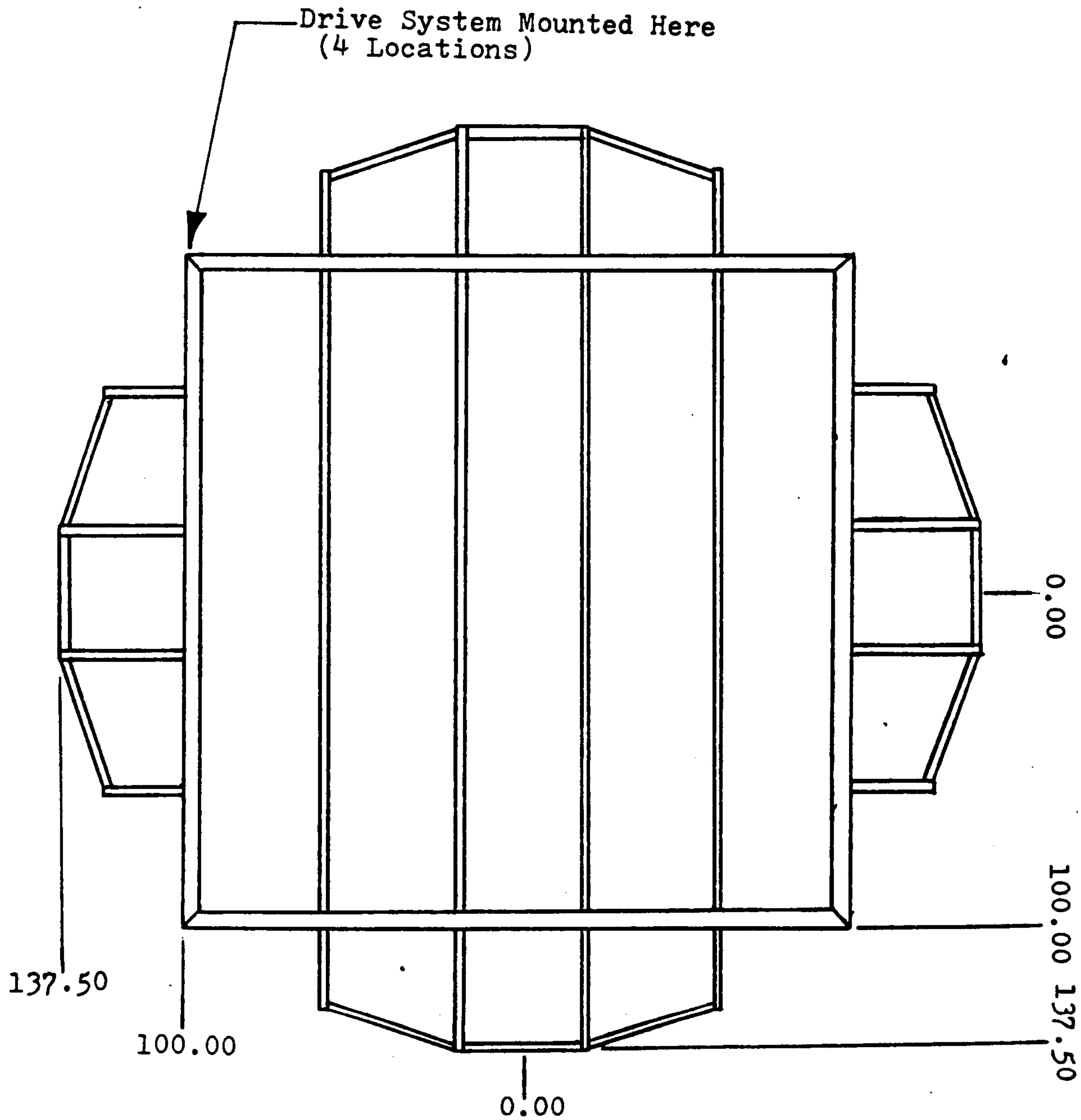

Fig. 5 Floor Structure
Top View

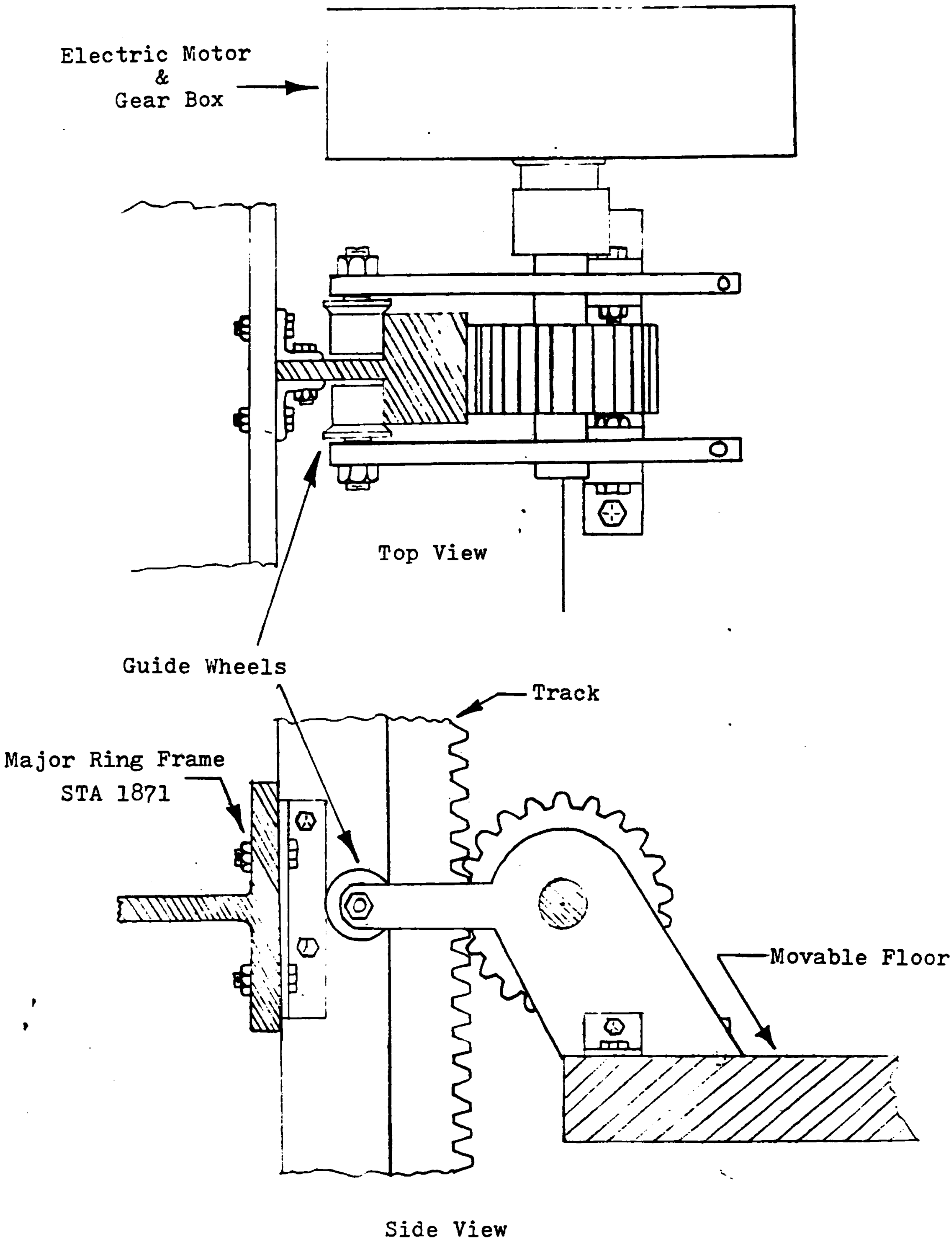

Fig. 6 Floor Drive System

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CHAPTER 4

Orientation of Spin

by

Anthony C. Lamo & Mark G. Eagon

4.1 Definition of Topic

Orientation of spin is defined as follows: How the VGF will be spun in relation to the orbital plane of the earth. How the habitated modules tumble in relation to the spin axis, and the earth.

4.2 Backround Information

We will be using a three capsule system with the two outer modules being VG and the center module to generate power and to provide a docking point. We know that the VGF must spin so as to produce artificial gravity. We must also be able to point the solar arrays towards the sun.

4.3 Proposed Mission Requirements

The mission requires that the VGF rotates on an axis that is feasible for long term orbit about the earth in such a way as to minimize the need for spin-orientation maintenence.

4.4 Proposed Method of Meeting Mission Requirements

The proposed method of meeting the mission requirements is to spin the VGF so that the plane of its rotation is approxamately one degree off the plane of its orbit about the earth. The VGF is stabilized by giving it a rotation about its geometric axis A-A (figure 1) in the direction indicated. A small and slow precession of this axis about a fixed Z-axis in space is observed, thus, resulting in a cone of precession.

4.4.1 This is a result of the physical dynamics of a rotating body in space. If spun in this way the VGF will be inherently stable and will continue in this motion with no orientation adjustment needed. The solar array for power generation will move about the Z-axis but only to a small degree because of its close proximity to the geometric center of the VGF. Thus, a despun solar array will be required to keep the power generation panels towards the sun. This method will also result in an even distribution of cosmic radiation over the surfaces of the living modules as well as the central capsule.

4.4.2 Weight Estimate of Proposed Method

Spin orientation is not equipment dependent.

4.5 Alternate Methods of Meeting Mission Requirements

4.5.1 To change the plane of rotation approxamately ninety depress or so that it is about one degree plus or minus from the earths surface. The orbital spin-dynamics would remain the same but the living modules would receive an unequal radiation load. A possible solution to this would be the adaptation of a combination solar array/radiation shield onto the surfaces of the living modules.

4.6 Disscussion of Unresolved Issues

How will spin dynamics be affected by uneven weight distribution in the VG modules? An answer to this problem might be the use of variable length tethers on the VGF, but would have to be monitored constantly or automatically computer controlled.

How will docking with the space shuttle be carried out with the end or the center capsule moving in a circular of conical motion? This might be done with the use of a flexible, rubberlike docking tube that could be stressed and twisted with little or no force being exerted on the spinning VGF system.

4.7 Conclusion

The placement of the VGF in orbit is a very technical problem. Certain laws of motion must be observed. And things such as heat loading, rediation shielding, power generation and docking must conform to these laws. It is felt that these problems can be overcome with more research in specific areas. The life sciences research that will be conducted on board the VGF is essential if we are to explore the heavens.

4.8 References

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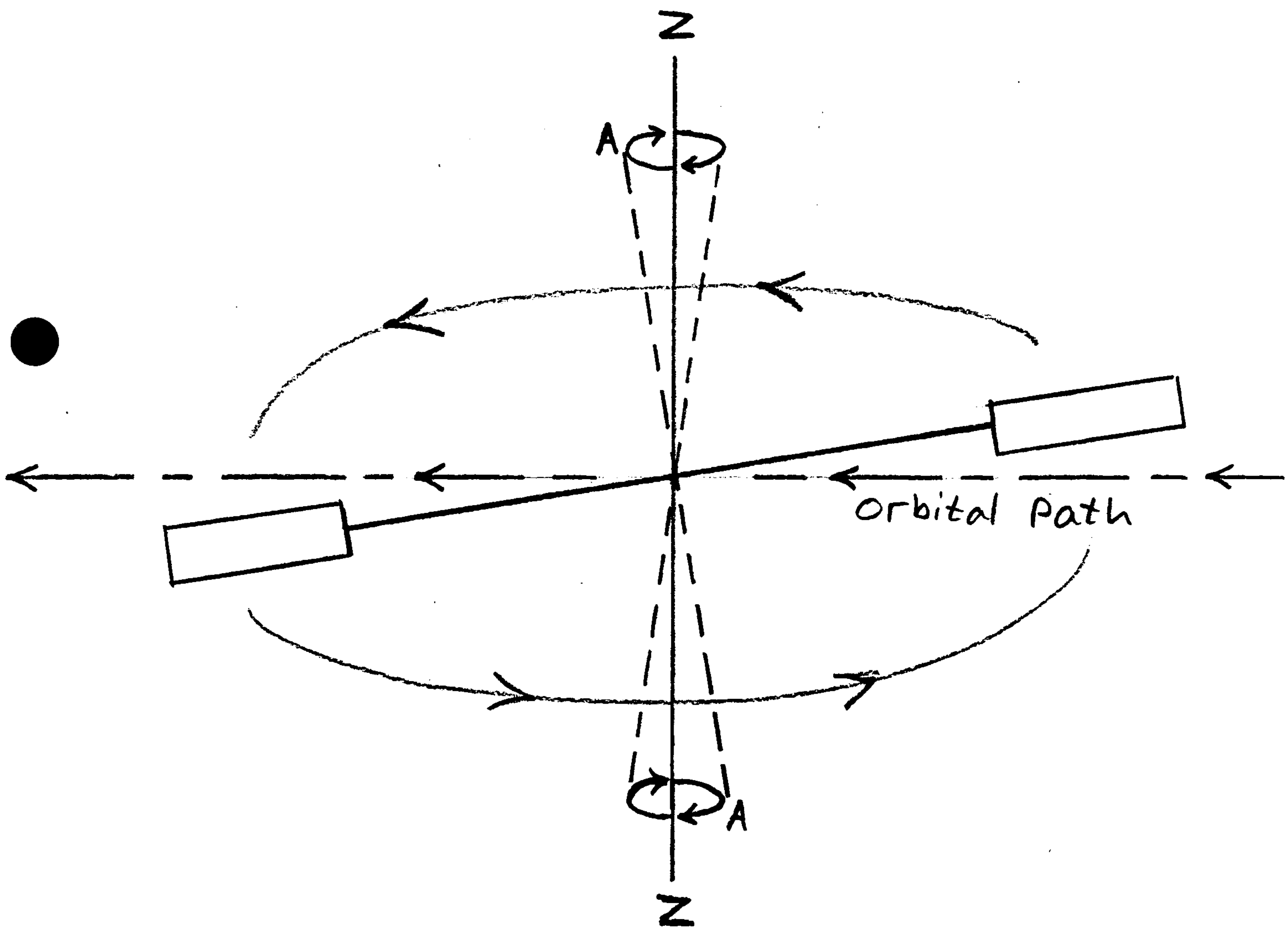
4011 Seltzer, S. M., D. W. Justice, G. Schweitzer, and J. S. Patel. 1972. Stabilizing a spinning skylab. 7 p. Huntsville, Alabama: Brown Engineering Co.

Spin orientation
(figure 1)



Chapter 5
Central Capsule
Scott Udell
Kevin Cameroon

5.1 Definition of Topic

This chapter deals with the possible configurations of the central capsule of the Variable Gravity Research (VGR) facility (both internally and externally).

5.2 Background Information

This report assumes a station configuration as defined in the class (Avit. 370, Space Studies II:VGR Facility, Spring Semester, 1987, University of North Dakota) handout of 1/14/87, specifically a station consisting of 3 modules (2 with pseudo-gravity, 1 central module) connected via 2 support tethers. Modules will be sized to fit in the Space Shuttle cargo bay. The module dimensions will be 45.5 feet in length, and 13.8 feet in diameter (a cylindrical shape is assumed), as specified in class on 1/14/87. It is assumed that at least a portion of the central module will be "de-rotated" to provide a stable point for shuttle docking.

Several questions about internal central module usage need to be considered:

1. Will the module support zero gravity research?

   This report suggests that zero gravity research be performed in addition to the variable gravity research being performed in the outer modules. Several documents that discuss experiments/applications already in use, or planned for the future, are listed in the bibliography (05002, p 1-32) (05010)(05011)(05012).

   The question has been raised "why even do zero-g research--that's what the space station is for." There are at least two answers to that question.

   First, the crew of the VGR facility will need something to do--very little has been proposed in the way of variable gravity research other than the physiological testing of the crew--the people are the experiments. Since it is likely that most of the evaluation of the results of this experimentation will be performed by ground-based personal, it leaves very little for the crew to do.

   It has also been proposed that there is a need to study the effects on humans of moving regularly between zero-g and variable-g environments (to simulate living on a "gravatied" station and working at a zero-g, say, construction site). If some of the crew had daily (or at least often) work to perform in a zero-g central module, such effects as mentioned above may be studied.

   Secondly, the central module could be used for zero-g research that might not be suited for the space station environment. Since the central module is essentially isolated from the two main habitation modules, it would be well suited to either dangerous or just plain bothersome experiments. One good example of this is zero-g animal research. Animals can be dirty, smelly, and noisy; and in the close, connected confines of the space station, they could quickly become intolerable. If, however, they were placed in the central module of the VGR facility, they would be out of sight (and sound and smell) of the living areas of the station. The book Engineering and Configurations of Space Stations and Platforms (05006, p 72-73, 102) describes facilities for animal/plant experimentation that would take up approximatly half a station module (lengthwise), assuming a station module diameter of 14.5 feet (external surface to external surface)(05006, p 540) and an interior height of 108 inches (05006, p 80).

Whatever the reason, zero gravity research space will be at a premium, even considering the space station.

2. Will the central module be continuously manned (around the the clock), will it only be used part-time (i.e. as a work/lab area), or will it only be used as an unmanned module?

Even though class specifications called for possible stays in the central module of up to 90 days, this report will assume that the module will be used as a workspace and/or storage space only, and that, except for emergencies (see below), all habitation will be in the outer modules. This eliminates the redundancy of toilets, food preparation, sleeping areas, etc., and makes room for functions that cannot be performed in the external modules. This assumes that the elevator(s) between the modules can operate in regular cycles (say, at least one cycle an hour) between the center and outer modules, thereby providing ready access to the facilities of the outer modules.

For emergencies, however, longer term habitation of the central capsule may be needed. For this a "safe haven" should be provided--up to 20 days of food, clothing, bedding, and other supplies normally provided by the outer modules (05006, p 105). Of course, if the central module is used as storage space for the outer modules, the safe haven need not be provided, since its function is already intrinsic in the function of the central module.

3. Will the central module be used for supplies storage?

This report assumes neither yes nor no for this subject--it has little effect on the overall external configuration of the station; and storage and equipment racks could be placed in either the central or outer modules (in most circumstances). It must be noted that if supplies are stored in the central module (espcially if it is used for all the facility's storage) the elevator system must be reliable and able to operate fairly extensively (as discussed above in 2.).

4. Will the central module be used to house equipment used by the entire station (computers, communications equipment, etc.)?

As in 3., this report assumes neither yes nor no. There are several advantages to this, however. By removing equipment needed by the entire facility, but not directly needed for habitation (like a toilet is directly needed, but the main computer is not), to the central capsule, yet more room is opened up in the habitation modules (an important factor when considering that crew will be living for periods of up to two years in modules of 318 square feet, maximum).

If the central module is de-rotated, it could also be used for the external mounting of equipment such as radio antennae, solar power equipment, and exterior scientific equipment (telescopes, radiation monitors, etc.).

5. Will the central module be used for the storage of propellant used in spinup and orbital manuvering?

This is a difficult question to answer. If spinnup is accomplished using liquid fuel rockets mounted on the outer modules, fuel, of course, will be needed in the outer modules. However, fuel in the outer modules would need to be spun up along with the rest of the mass of the modules, and since the amount of liquild fuel needed is likely to be fairly large (05016) (though, not as large as originally estimated (05009, p 95-99)), fuel storage in the outer modules would not be effective (in either space used or weight limitations).

Fuel placed in a de-rotated center module eliminates the need of rotating the fuel's mass, and allows for more habitation space in the outer modues. However, it creates other problems-- first, how to pump fuel from a non-rotating central module out to rotating modules up to 320 feet away through piping that must be able to change in lenght and that can withstand extremes of heat, cold, radiation, and pressure; secod, how the de-rotation mechanism handles the large amount of mass required by the fuel.

5.3 Proposed Mission Requirments

The central module (and also the outer modules) will be designed as closely as possible along the lines of the space station module model. This will save both design time and production effort (and therefore money). As specified in section 5.2, the central module will serve at least as a docking point for the shuttle.

Other requirements for the center module vary, depending on many factors. Internal usage requirements also effect directly external design--some things can not be done well (or at all) if the station is designed in a certain way, and some external configurations are very hard to implement if the centeral module is needed for some internal purpose. For example, if the central module is used for micro-gravity experimentation, the entire module will need to be de-rotated to eliminate the (even minor) gravitational effects. This would in turn dictate certain station configurations. The central capsule docking facilities should be able to dock with free-flyers, have Soviet dock capabilities, and should be able to receive an astronaut/MMU (05014, p 8). It might also be wise to require that the VG facility be "affordable by the private sector" (05014, p 14) and have the ability to use "non-shuttle options" (such as heavy lift launch vehicles now under development)(05017).

5.4 Proposed Method of Meeting Mission Requirements

The VGR facility will consist of a de-rotated central module with a shuttle docking port at one end and another derotated member of equivalent mass balanced opposite the first, with a rotating central portion to which the tethers to the outer modules are attached (see figure 1a). The outer, spinning modules, with this configuration, will be mounted "in the spin plane for inherent stability" (05013).

Configuration of the spinning component could be in three forms:

*A rotating axle of approximatly 50 feet in length to which the tethers are attached (see figure 1b).

*A wider structure acting as the axle in the first method, for better lateral stability during shuttle docking (see figure 1c).

*The outer modules held length-wise and attached to a small rotating portion of the central structure (see figure 1d).

5.4.1 Discussion of Proposed Method

This configuration has many of the same advantages and disadvantages of that discussed in 5.5.3. It solves the instability problem of the configuration discussed in 5.5.3 by orienting the outer modules in the spin plane. It has the potential for being less stable when docking with the shuttle, and the design of the central rotating member would probably be much more complex.

The three sub-configurations of the rotating portion also have various advantages/disadvantages. The first (figure 1b), with its single-piece axle is much simpler than the second axle-type structure as presented in figure 1c, but probably much less stable during docking. The second version is also much heavier. Both versions must have the elevator operating from the center of the outer modules instead of the ends, thereby necessitating airlocks in the middles of the modules. This, in addition to taking up room, introduces a large variation from the space station standard.

The third configuration is proposed to be the "configuration of choice." This came about after hearing presentations by Dr. Brian O'Leary and Major Alex Gimarc, a conversation with Major Gimarc, and reading a paper by Major Gimarc. Both proposed that the rotating modules be held length-wise. The other alternatives, according to Major Gimarc (as seen in figures 1b and 1c) have the potential for being unstable unless most of the mass of the modules is located in their centers (05018). While the ideal configuration would be two shuttle external tanks, as in Major Gimarc's paper (05014, figure 8), to stay within class guidelines, standard space station modules reconfigured for a length-wise orientation are proposed. A configuration such as this was proposed by Dr. O'Leary (05019). This configuration, divided up into 4-6 single-room 'floors' of approximatly 49 sq. feet apiece provides about the same floorspace as the configurations in figures 1b and 1c, but has potential negative psychological effects (although this has not yet been ascertained).

The "other derotated member" mentioned in 5.4 is necessary to insure that the center gravity for the facility is correctly positioned (05018). While this member must be of nearly the same mass as the main central module, it could be any of a number of other items, including:

*another central module, exactly the same as the first.

*a fuel/supplies storage module
*a solar power array (either photovoltaic or solar dynamic)
*a nuclear power generator
*an OTV facility
*a non-preasurized scientific platform, or a telescope

If we conform with the suggested standard of using only space station modules for all our modules, a minimum of 5 flights would be needed to place this configuration. Ironically, using the ETs for the outer modules (thereby providing much more space than space station modules and the ability to perform experiments at several different gravity levels at once) reduces the number of flights to a maximum of three.

Such a configuration would alleviate several problems. First, it would provide clearance for the shuttle's tail, which is approximatly 25 feet high (05007, p 7.4-7.5)--a major problem when rotating tethers are involved. Secondly, by extending the center module away from the tethers, large arrays of external equipment (solar panels, antennae, etc.) can be mounted and repaired without the problem of tether interference. Thirdly, this design would be much simpler to de-rotate--the whole capsule is de-rotated. Fourth, the reels to wind up the tethers could be mounted on the central rotating member, creating more room in the outer modules, although "live" tethers (reels at both ends) might be desirable for safety purposes (05014, p 8). Fifth, having a central rotating member that is not a part of the central module eliminates many of the problems with having the tethers connected directly to the central module (see section .5.1, below).

Problems with such a design include:

*how to operate an elevator between rotating outer modules and a non-rotating inner module.

*how to make connections between the rotating and non-rotating capsules, especially in the case of electrical connections. This is a fairly major problem--fuel connections can be via rotating gaskets, but electrical connetions (both for electrical power and data transfer/communications) need to be constant. Satellites by Hughes Aircraft apparently have rotating electrical connections, so the technology does exist (05017).

5.4.2 Weight Estimate of Proposed Method

Space station modules will weigh (estimated) between 33,884 lbs up to 55,305 lbs, with most of the module weights falling in the upper 30,000lb range (05006, p 45). This report will assume a module weight of approximately 38,000 lbs, and a weight for other pieces (tether cables, elevator(s), axles, etc.) of approximately 20,000lbs (a wild guess). This would give an approximate total weight of 110,000 lbs (not including fuel or supplies). This would fit in with the 4-shuttle flights limit imposed in class.

5.5 Alternate Methods of Meeting Mission Requirements

5.5.1 The first configuration that came to the minds of students in the class consisted of two outer modules rotating about the central module, with a de-spun docking adapter on one end of the central module (see figure 2).

Such a concept has many problems if it involves a de-spun central module. Tethers would need to be attached to rotating portions (rings) of the central module, which would be very expensive to implement. The tethers would need to either pass through the center capsule, which would mean tricky (and unreliable) rotating preasure seals and a module design almost completly different from that of the space station modules; or to be attached on external rings, which means four seperate tethers and very strong attachment points.

Even if the central capsule rotates with the rest, there are still some problems. No sensitive zero-g work could be performed, and it could be very hard to work in a module rotating about you at a rate of 3 rpm.

There are also possible problems with orienting the modules out of the plane of rotation (050013).

5.5.2 Another concept, originating out of JPL, took the "central capsule" down to the bare minimum specified in section .2-- a docking position for the shuttle. The configuration was two outer capsules attached via a single tether, with two elevators. One of the elevators would have a docking position on it, and could be positioned such that the docking port was alligned with the axis of rotation, thereby making a mini central capsule for the transfer of personal and supplies only (05008).

This concept is echoed by Gimarc--a 'central point' consisting of only tether control, the elevator system, and a docking module (05014, p 8).

The JPL proposal, if one doesn't consider the fact that its "central module" has none of the abilities discussed in section 5.3, has very few problems. It would mean that the VGR facility would be very cramped, however.

5.5.3 The VGR facility would consist of a de-rotated central module with a shuttle docking port at one end and a rotating axle of approximatly 50 feet in length to which the tethers are attached. The elevator would operate off the ends of all the modules (docking with space station standard airlocks)--thus the modules used could be almost exact copies (externally) of space station modules, execpt for tether and axle fittings (see figure 3).

A rigid axle structure (compared to a single tether attachment at the end of the central module, with the other tether having no central attachment) is necessary because forces caused by the shuttle docking are significant enough to "flip" the central module up into the rotating tethers (05006, p. 126-127,149,188). With a rigid axle, the whole structure may move (correctable with positioning rockets), but the central capsule is no longer in danger of crashing into the tethers.

Problems with this design include

*as with 5.5.1, there are possible stability problems with orienting the rotating modules out of the plane of rotation.

*as discussed in 5.5.1, there are stability problems caused by extending the central module without a balanced, equivalent mass opposite it.

5.6 Discussion of Unresolved Issues

Both alternatives 5.5.1 and 5.5.2 have the problem of the shuttle's tail interfering with rotating tethers during docking. One way around this is to have an extendable docking tube (05009, p 240)(05014, p 14), either carried by the shuttle or extended from the central capsule's de-spun portion. Another possibility is a "mobile module" that could be lifted out of the shuttle bay and attached to the facility with the shuttle's arm (05014, p 14) (05015).

The issue of gyroscopic effects upon the spinning station caused by shuttle docking have not been studied. A way to get around the forces of shuttle docking may be to use the shuttle's robot arm to pull the shuttle into docking position, or to use one of the alternatives discussed in the paragraph above.

5.7 Summary

Whatever the configuration choosen, a central module offers so many benefits to its cost that it should not be discarded without considerable thought. It does introduce more complexity into the system (and more cost), but also much more flexibility. It allows for potential station growth, and with a central module the VG research facility could be converted into a permanent orbiting space station with 1 g living facilities, or even into a lunar station or a Mars mission vehicle.

5.8 References

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05018 Gimarc, A. 1987. Personal communications to Scott Udell, April 22, 1987. r.e. stability issues of tethered vg facility concepts.

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Figure 1a

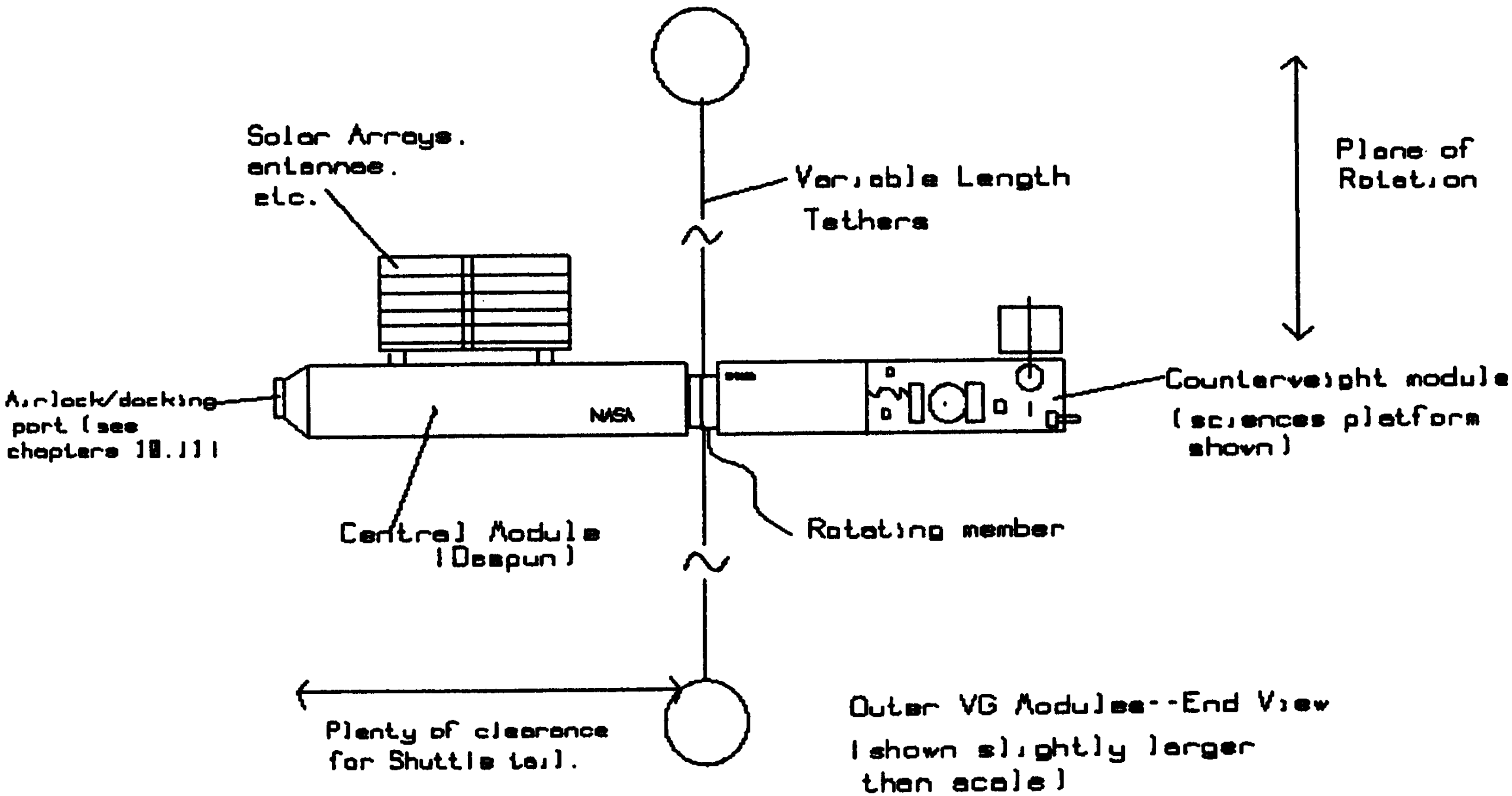

Solar Arrays, antennae, etc.
Variable Length Tethers
Plane of Rotation
Airlock/docking port (see chapters 10,11)
NASA
Countervsight module (sciences platform shown)
Central Module (Despun)
Rotating member
Plenty of clearance for Shuttle tail.
Outer VG Modules--End View (shown slightly larger than scale)

Figure 1b

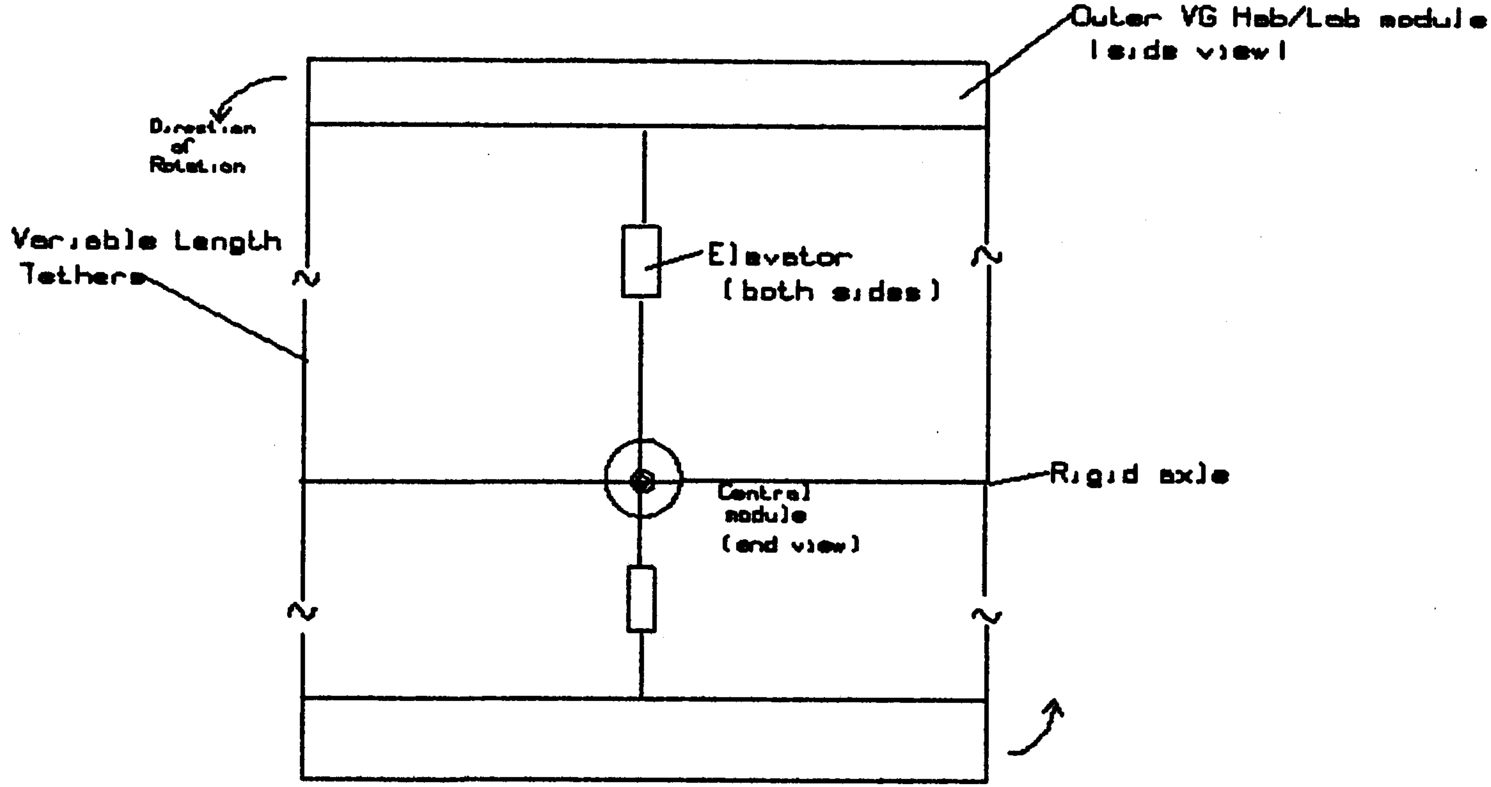
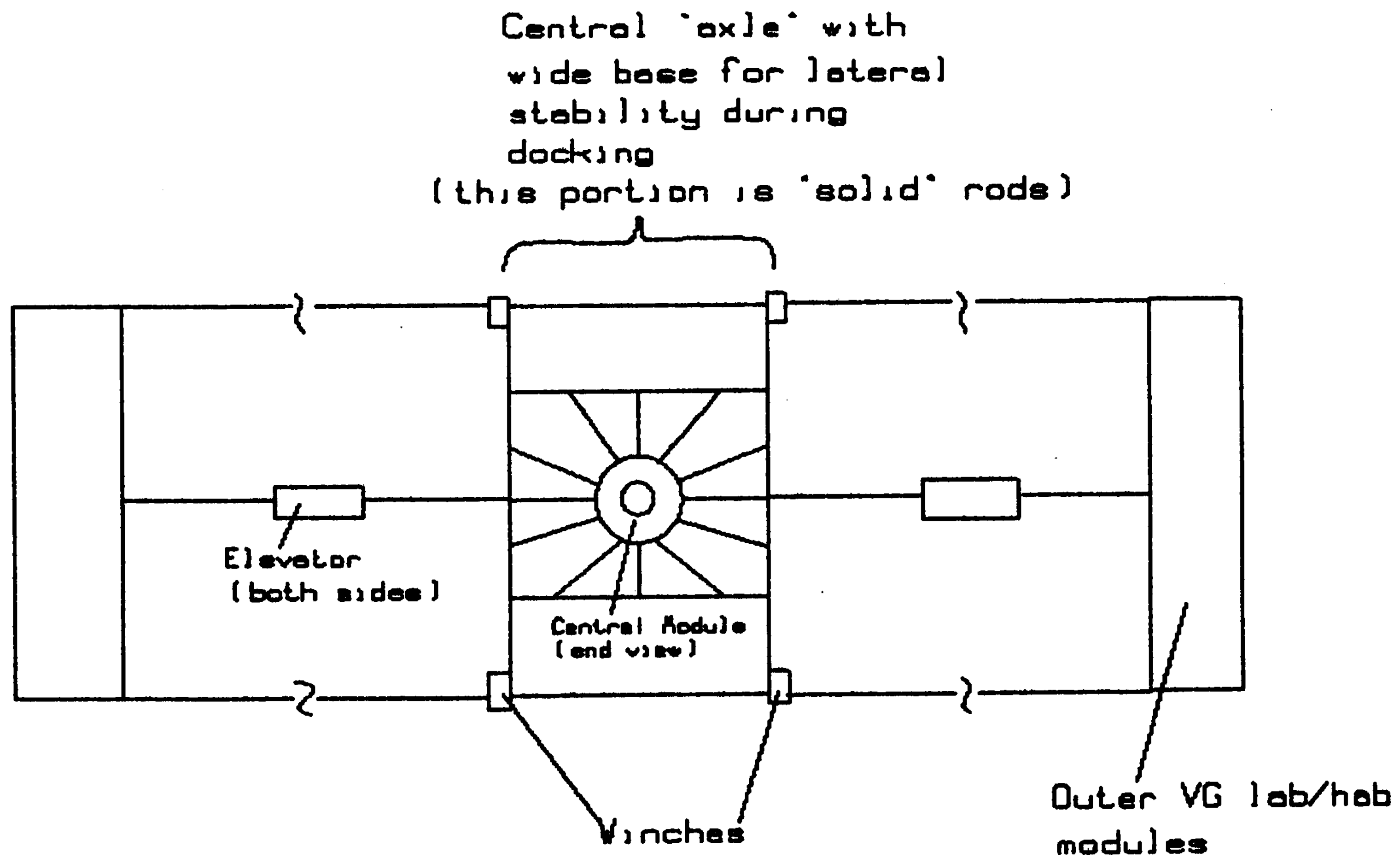

Outer VG Hab/Lab module
(side view)
Direction
of
Rotation
Variable Length
Tethers
Elevator
(both sides)
Rigid axle
Central
module
(end view)

Figure 1c



Alternate in-plane-of-rotation
configuration As proposed by
Dr. Dick Parker, UND

Figure 1d

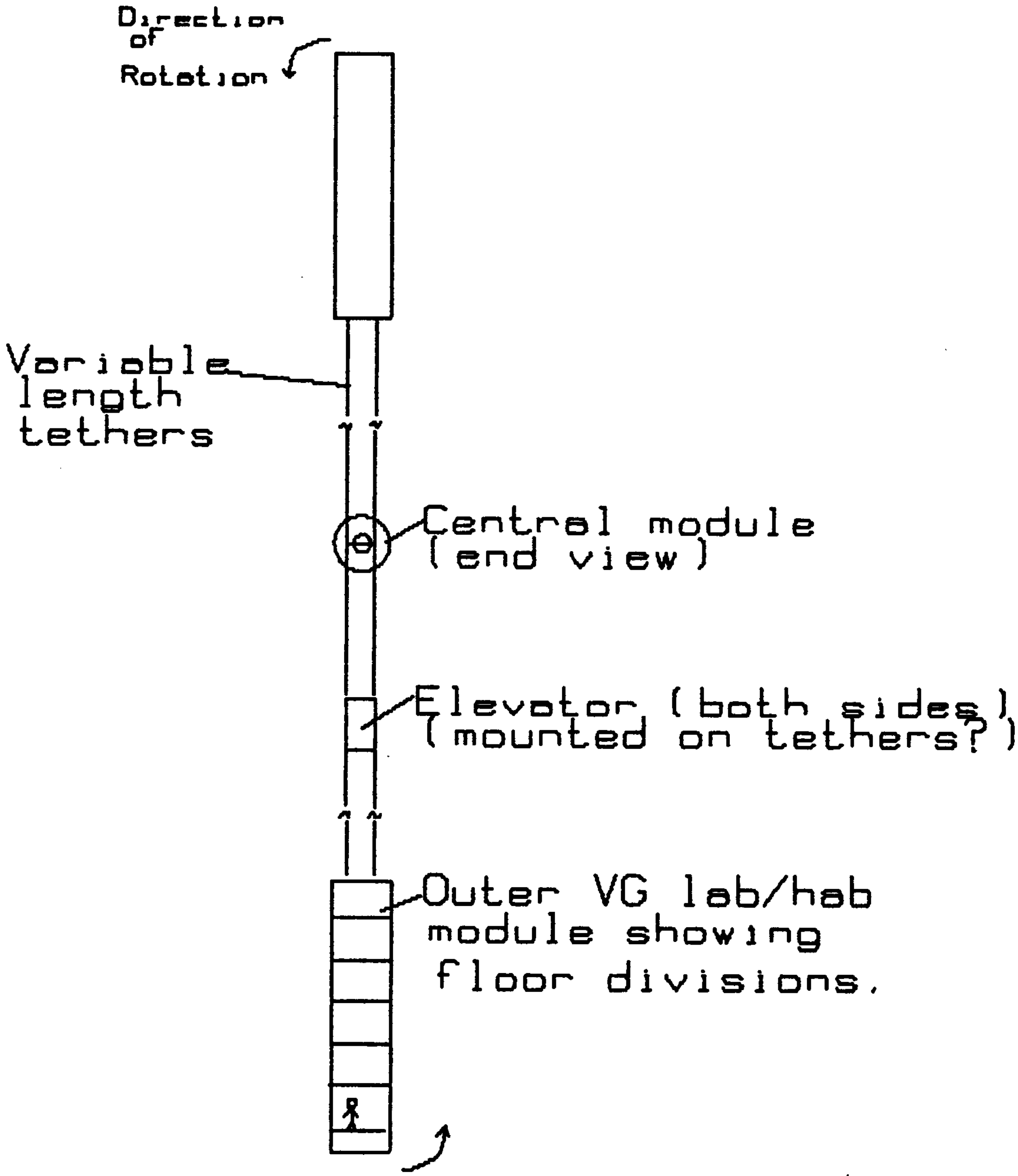

Direction of Rotation
Variable length tethers
Central module (end view)
Elevator (both sides) (mounted on tethers?)
Outer VG lab/hab module showing floor divisions.

Figure 2

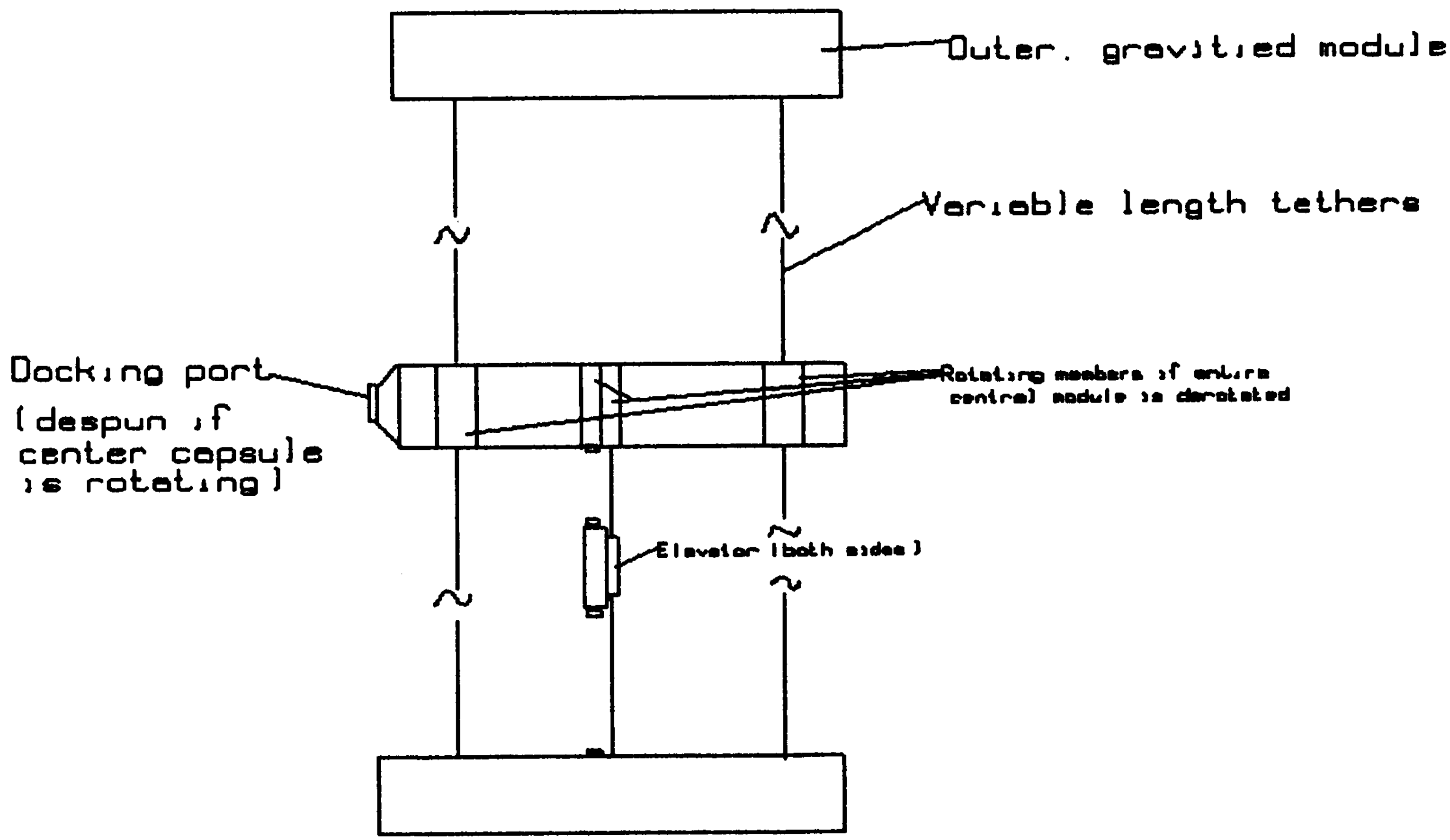
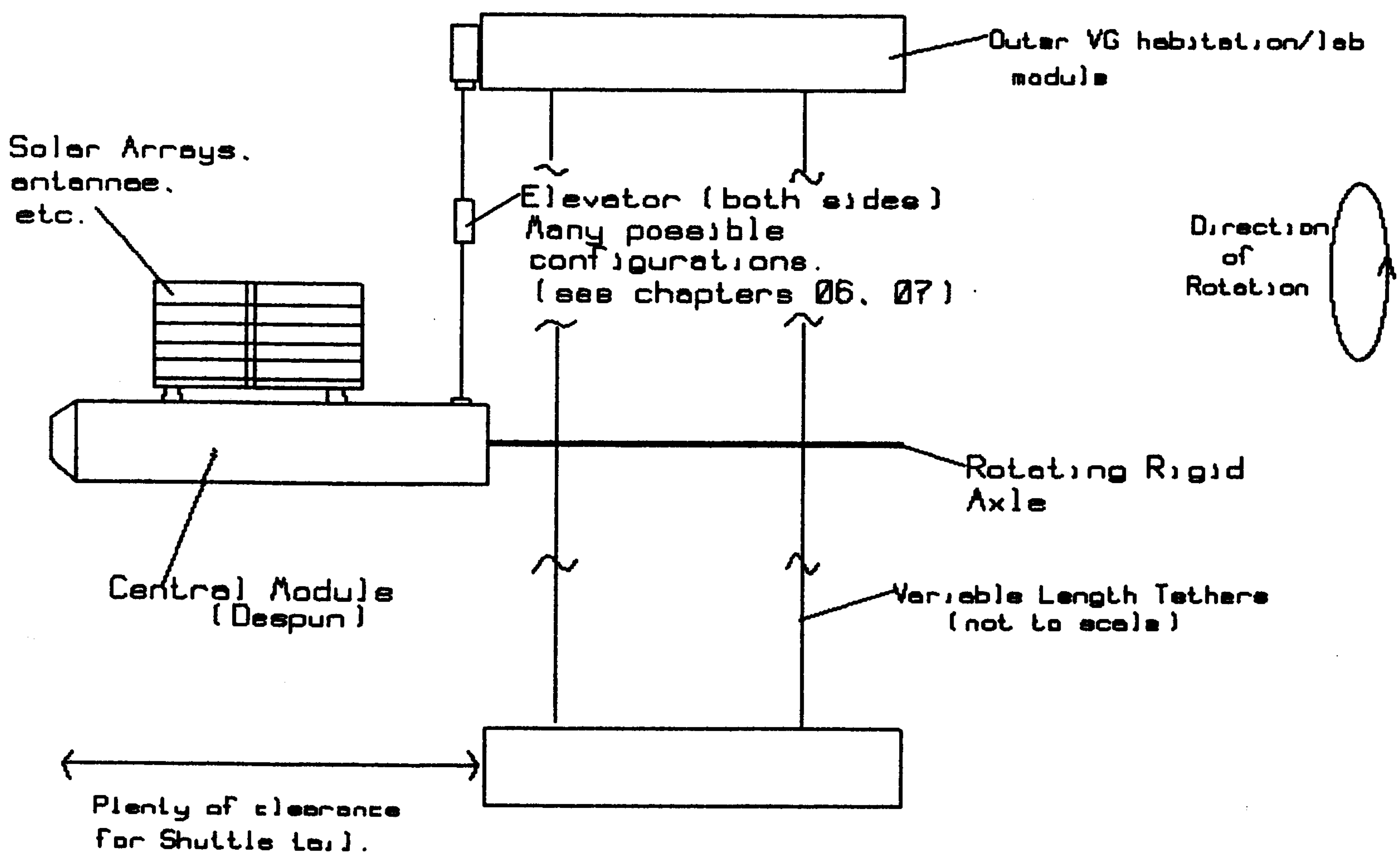

Outer, gravitied module
Variable length tethers
Docking port
(despun if center capsule is rotating)
Rotating members if entire central module is derotated
Elevator (both sides)

Figure 3



Outer VG habitation/lab module
Solar Arrays, antennae, etc.
Elevator (both sides)
Many possible configurations.
(see chapters 06, 07)
Direction of Rotation
Rotating Rigid Axle
Central Module (Despun)
Variable Length Tethers (not to scale)
Plenty of clearance for Shuttle tail.

Chapter 6

Elevators

By

Kevin Cameron and Scott Udell

Section 06.1

Elevators :

This Topic Covers :

A means of getting from the outside module to the center module; a means of getting from the center module to an outside module.

All diagrams referred to in the following sections are found in section 6.9.

Section 06.2

Background Information and Assumptions:

Since The center capsule concept is an integral part of how the methods of getting to the center capsule and back are conceptualized there will be parts of this report that will go into depth of how the center capsule is designed.

The following assumption are made for the remainder of this chapter; they are:

1. It is necessary to have a place in the variable gravity station that is at zero G, because the object of this facility is to study the physical reactions of different beings or matter under all gravity levels up to one G.

2. Since the main variable gravity station is spinning, the center capsule should counter spin. This spin should be at such a rate as to make it motionless to a vehicle approaching it to dock, this vehicle coming from a standard orbit.

3. A spinning air tight seal is difficult to maintain. This assumption was made on inspection of the nature of a spinning air tight seal and is due to the lack of available reference material on the subject.

4. All elevator designs will be designed to be implemented into the general design of the variable gravity facility given in diagram 6.1a. This is to give a standard reference to aid in elevator design.

5. This facility will be in an orbit such that the low orbit micro meteoroids will not be a problem. This is because the earth has low orbit debris from previously objects put into orbit.

6. There must be a way to get to each of the outer capsules.

7. There will be a standard airlock available.

Section 06.3

Mission Requirements:

The method referred to in this section is the method of getting from the outer capsules to the center capsule and back.

1. The total equipment necessary to implement the method must not fill more the two - fifths of the shuttle cargo bay.

This is to allow room for other final parts of the variable gravity station to be placed in the cargo bay.

2. The total weight of the equipment needed for this method can not weigh over two - fifths of the shuttle cargo bay lift capacity.

This is to allow room for other final parts of the variable gravity station to be placed in the cargo bay.

3. The method should be able to withstand a collision with a small meteoroid concurrent with the specifications of the rest of the station.

The strength and tolerance of the method should be the same as the rest of the station. If this section of the variable gravity facility has a collision with another object, it will not be disabled easier than the rest of the station.

4. The method should allow for any people or cargo that can be transferred from the shuttle to the center capsule, to be transferred from the center capsule to the outer capsules.

This is to allow anything that may be needed for operation to be transferred to the outer capsules.

5. The method should allow a person to be transferred in an atmosphere that will support human life.

This is so there will be no need to have special transfer containers to transfer animals. The thought of not having the method have an atmosphere that will support human life, just an air lock at the end of each of the capsules, with a pathway of some kind between capsules, was considered. It was obvious that more problems transferring animals and supplies would arise than would deem that method practical.

6. Cost will not be considered for this method unless, by inspection, it is determined to be a reasonable factor.

Cost will not be a factor in designs presented unless, by inspection, a part of the method is unreasonable to build because of cost. An example:

Developing a bread of reindeer that can fly cargo to this station would not be cost effective.

7. Any part of a method can be of any size or weight as long as the total weight and size meet mission requirements one and two.

Any part can be any size, shape or weight as long as it fits into the above described guidelines. It must fit in the shuttle cargo bay.

Section 06.4

Method of Meeting Mission Requirements:

All diagrams referred to in this chapter will be found in section 6.9 after the references. They are represented as Diagram #; this is an example:

Diagram 6.4a

Looking in section 6.8 after the references the above mentioned diagram would be followed by a diagram of the connection between the center capsule and elevator docking module.

In this section:

1. A brief summery will tell how this method works.
2. An in depth review of how all of this methods parts work.

1. Diagram 6.4 is a diagram of the overall workings of this method. The following brief summary will be based on this diagram.

The elevator crawls up and down the elevator cables to dock with the outer modules or with the outer catch ring. When docking with the outer modules it crawls against the outer capsules the elevator is docked. This is nothing more than a standard docking routine. There are no special connections. The elevators are held on by the airlocks and the elevators own weight. To get to the center module the elevator crawlers dock to the shift guides. The shift guides work as a bridge between the elevator crawlers and the inner catch ring. The elevator crawls off the crawlers and into the inner catch ring. The elevator locks onto the elevator guides. It is spun by the inner catch ring to the orientation of the center capsule. The elevator guides push the elevator into the center capsule, docking it. There is only one top to the elevator (The top is indicated in diagram 6.4.). If leaving the elevator docking module the top air lock must face in the direction of whichever outer capsule the it is heading toward.

2. Diagram 6.4a represents the connection between the center capsule and elevator docking module. At the end of the center capsule there is a magnetic field. This magnetic field is given of by the magnetic ring. A similar ring is on the docking module. Together they allow the elevator docking module to spin on the end of the center capsule. The counter spin of the center capsule is controlled by an electromagnetic propulsion system. This system is located at the end of the center module and is implemented in such a way as to not block access to the airlock at the top of the center capsule (Top and Bottom are described in the referred to diagram.). The specifics of this electromagnetic system will not be discussed in this report. This system will be studied further in future reports.

At the end of the center module there is a standard air lock. This airlock will be used to dock with the elevator. The process of docking with the elevator will be discussed further, later in this section.

The elevator docking module, represented in diagram 6.4b, is used to catch the elevator and spin it to the orientation of the center module. In diagram 6.4c the outer catch ring is represented. This part of the elevator docking module continuously spins with the outer capsules. It is noted that the center capsule also always spins in the opposite direction in compliance with the assumptions made at the beginning of this chapter. The shift guides also, in diagram 6.4c, on the outer catch ring, have no moving parts they are permanently attached to

the outer catch ring. The shift guides allow the elevator to crawl into the inner catch ring. working as a bridge from the elevator crawler tracks to the inner catch ring. The elevator crawler tracks will be discussed later in this section.
The shift guides also have locking wings which are stationary and are permanently attached to the shift guides. These wings are used as part of a docking mechanism on the elevator crawler track, which will be discussed later in this section.

The inner catch ring, represented in diagram 6.4d has three elevator guides, the elevator locks onto these guides and is spun to the orientation of the center capsule by the entire inner catch ring. The hydraulic lifts then push the elevator into the center capsule docking it. It is noted that the elevator guides are fixed to the inner catch ring in such a way as to allow them to only be moved toward the center capsule and back by the hydraulic lifts; they can not move perpendicular to this motion.

The elevator has three elevator crawlers, shown in diagram 6.4e, these crawlers are shape the same as the elevator guides and line up with the shift guides of the outer catch ring. The elevator crawlers in diagram 6.4e have two grab wheels which have a groove on them so that it pinches the elevator cable between itself and the elevator grab wheels. These elevator grab wheels are driven by an electric motor. The motor is inside the elevator crawlers and drives the grab wheels to cause the elevator to go one way or another on the elevator cables. At the top of the crawlers there is a elevator stop. This stop keeps the elevator from running off the end of the elevator crawler. At the bottom is a docking mechanism which locks onto the wings of the shift guides (The shift guide wings are shown in diagram 6.4c.). This allow them to dock to the outer catch ring so that the elevator can crawl off of them, so that it can crawl into the inner catch ring.

The elevator, shown in diagram 6.4f, is 8ft in length and has a diameter of 8ft. It is a symmetric cylinder. The airlocks extend 1/2ft from the elevator. There are two airlocks, the one on the top (The top is shown in diagram 6.4f.) is for docking with outer modules, the one on the side is for docking with the center module. The elevator crawl wheels are equipped with locking pegs which allow them to lock onto the elevator crawlers, in the elevator grooves, in the peg wholes (The elevator groove is shown in diagram 6.4e.). The elevator is in line with the peg wholes when it pushed up against the elevator stop. The elevator are shaped like a funnel to allow the pegs 1/2 inch leeway when lined up with the elevator stop on the elevator crawlers. It is noted that these peg holes are on the crawlers.

On both the outer capsules there are elevator cable winches (This is shown in diagram 6.4g.). These winches are driven by electric motors on the outer capsules. The elevator cables pass through simple pulleys that are in line with the three elevator crawlers. The cable then passes through a small series of these casters to guide it to the elevator cable winches located on the on either side of an outer modules.

All docking is done with standard airlocks. There is no special locking mechanism at either of the outer capsules because by inspection of the nature of the facility, the weight of the elevators will keep them airlocked.

To increase the distance between the two outer modules, the cable winches let out cable equal to the amount of tether being let out. (060010)

Section 06.4.1

Discussion of Method of Meeting Mission Requirements:

Disadvantages to this are:

1. The exterior parts of this design will require EVA for servicing. EVA is dangerous and expensive.

2. The elevator would have to be equipped with a drive system to enable it to crawl on the cables. The batteries and other necessary parts could limit room in the elevator.

3. All elevator drive parts and counter spin drive parts are exposed to possible meteoroid collision. If a meteoroid hit the elevator docking module the entire elevator system could be disabled. This would then cause the center capsule to spin, making docking with the shuttle to get needed parts for repair difficult.

Advantages to this method are:

1. It does not take up any of the center capsule leaving the entire center capsule for other use.

2. It has less mass than all other methods mentioned in this chapter. This would allow room for more equipment to be brought up with this shuttle load when this method is implemented. This would also reduce cost proportionately.

Section 6.4.2

Weight Estimate of Proposed Method

Two - fifths of the shuttle cargo capacity.

Section 06.5

The following is a brief summary of some of the designs in this section. More complete descriptions of these designs are given later in this section.

Basically all designs can be grouped together and interchanged. There are two different ways to get to an outer capsule, by elevator or by a flexible accordion like tubes.

As for individual elevator designs there are two also. The first type crawls back and forth on the elevator cables. This type is not fixed to the cables. The other type of elevator is the fixed to the elevator cables. The cables pull it back and forth by way of winches located on one of the three capsules.

The last main part is the configuration of the end of the center module. There are three different designs. The first design spins the elevator to the orientation of the center capsule. The next type works generally the same except it does not spin the elevator. Instead, it has a transfer module between the center capsule and the elevator docking module which transfers people from the spin of the center capsule to the spin of the elevator docking module or vise versa. The final type has three pressurized modules. It is essentially the same as the last design discussed, except the elevator docking module is a pressurized module equipped with docking ports on either side.

All of the parts described in the above paragraphs are interchangeable on any design. The following designs are just some of the ways that these parts can be assembled.

Section 06.5.1

Alternate Method of Meeting Mission Requirements.

The magnetic rings in Diagram 6.5.1a work the same as the magnetic rings in the section 6.4. The center module is spinning at the same rate as the outer module, accept in the opposite direction. The transfer module shown in diagram 6.5.1b has airlocks at both ends. Its purpose is to lock on to the center module or the elevator and dock with it. For instance; if an astronaut was in the center capsule and needed to get to the elevator, the transfer module would lock onto the center module and dock to it. He then could open the airlock and enter the transfer module, thus leaving the center module. Once in the transfer module he would secure himself and any cargo he might have with him. The transfer module would then let go of the center module and lock onto the elevator docking module. This action would cause the transfer module to spin at the same rate as the center module, but spinning in the opposite direction. After the elevator has entered the elevator docking module it docks with the transfer module. The astronaut can then open the airlock and enter the elevator.

The elevator docking module shown in diagram 6.5.1c rotates with the outer capsule at all times. The elevator is pulled into the elevator cable guides by the elevator cable winches (described later). The elevator guides then clamp onto the elevator. Each elevator guide is equipped with a hydraulic system which allows it to move from the start position (see diagram) to the extended position (see diagram). This docks the elevator to the transfer module. This process is repeated in reverse to separate the elevator from the transfer module.

The elevator in this design is fixed to the elevator cables, elevator depicted in diagram 6.5.1d. The elevator in this design does not crawl on the cable but is instead pulled back and forth by the elevator cables. The elevator fins which the elevator cables are fixed to are two inches thinner than the gap in the elevator guides. This allows the fins to easily slide into the elevator guides for docking.

There are three dual elevator cable winches, winches shown in diagram 6.5.1e. The elevator cable in the winches goes from one side of the dual winch, through the elevator docking module, to the other outer module, through a pulley, back through the elevator guides, to the opposite side of the dual winch. These dual winches work together, one letting out cable while the other takes in cable. All three dual winches work in tandem in the above described way producing elevator movement.

When the elevator is pulled to either of the outer modules it docks with them. A standard docking procedure is used at either of the outer modules.

Section 6.5.1.1

Discussion of Alternate Method

Disadvantages to this are:

1. Maintenance to this system would require EVA. Most of the methods moving parts are outside the facility. These parts will eventually need to be serviced.

2. At least one crew member would have to stay at the outer capsules containing the winches in case the elevator jams. It is assumed that the outer capsule with the winches would be the

habitation module in order for this to be accomplished effectively.

3. The transfer module would shorten the center capsule or would take up more space and weight than the method discussed in section 6.4 if brought up separate from the center module. This would make this method less cost effective.

The advantages to this design are:

1. This design does not disconnect the elevator from the elevator cables or spin the elevator. Despite having more volume there are less moving parts, the design is more simple than the design in section 6.4. There is less need for exterior servicing.

2. This designs elevator motion system (method of moving the elevator) does not crawl on the cables. There will be less wear on the elevator cables do to slippage which might occur in the elevator motion system discussed in section 6.4.

3. This designs elevator motion system does not crawl. This system is less likely to get jammed by debris, and is less likely to be affected by any build up of materials on the elevator cables.

Section 06.5.2

Alternate Method of Meeting Design Requirements:

There are only two differences in this design from the design discussed in section 6.5.1. The first, shown in Diagram 6.5.2a and 6.5.2b, is the elevator docking module. The elevator docking module in this design is docked to by two elevators. It is a fully airtight module. It has one airlock that is used to dock with the center module, and has two addition airlocks which are used to dock with the two elevators.

The second difference is the addition of an elevator and the position of the elevator cable winches. The two elevators are moved back and forth by the same drive system as the design in section 6.5.1. The exception is that there is a set of three dual cable winches for each elevator, one stacked on top of another, shown in diagram 6.5.2c.

All other functions of this design work the same as described in the design in section 6.5.1.

Section 6.5.2.1

Discussion of Alternate Method

The disadvantages to this method are:

1. This method has even more volume than the method presented in section 6.5.1. It would take up even more room in the shuttle

cargo bay, or decrease the size of the center module even more than the design in section 6.5.1. This would increase costs because of the additional weight and size.

2. If this design was brought up in pieces, i.e. one piece the central module, one piece the transfer module and one piece the elevator docking module, it would make the assembly of the station would be more difficult. The extra time and EVA that might be needed drive up costs and increase astronaut risk in the assembly procedure.

The advantages to this method are:

1. This design would be more affective than the previous designs if frequent travel to and from both of the outer modules was needed. It would allow crew to use both elevators simultaneously.

2. All moving parts for the elevators are centrally located. This could make maintenance easier than the method presented in section 6.5.1. An astronaut would less likely be thrown off because the elevator docking module is at a lower gravity level.

Section 06.5.3

Alternate Method of Meeting Mission Requirements.

The transfer module of Diagram 6.5.3a is the same as in the design in section 6.5.1. The elevator docking module is the same as the elevator docking module in the previous section with the exception of having no elevator cable winches. To transfer people or cargo from the center capsule to the elevator docking module, the transfer module locks onto the center capsule and docks with it, the same as the design in section 6.5.2. When all people and cargo are transferred from the center capsule to the transfer module, the airlocks are closed, and the transfer vehicle lets go of the center module and locks on to the elevator docking module. The transfer module then docks with the elevator docking module. People and cargo are then transferred to elevator docking module. After the people and the cargo are transferred to elevator docking module the airlock between them is closed. This allows the transfer module to separate from the elevator docking module.

The elevators in this design are replaced with an airtight flexible tube. There are two different designs for this tube.

The first version is shown on diagram 6.5.3c. The flex tube is docked to the elevator docking module the same way an elevator docks with the elevator docking module. The only difference is that the flex tube does not separate. It stays docked at all times. People and cargo climb through the airlock leading to the outer capsules. They then climb down the ladders to the outer capsules. Movement toward either of the outer capsules is considered down. When people and cargo reach the outer capsules they climb into them through the airlock. It is noted that the flex tube is airtight and at the same pressure and air consistency as all three of the capsules.

The second version is shown on diagram 6.5.3d. People and cargo climb through the airlock from the elevator docking module to the flex tube and strap themselves to an elevator platform. It lowers them to the outer capsule and stops. People and cargo climb through the elevator hatch down through the airlock and into the outer capsules. Again it is to be noted that the flex tube is airtight and is at the same pressure and air consistency as all three of the capsules.

Section 06.5.3.1

Discussion of Proposed Alternate Method

Disadvantages to this proposed design are:

1. A suitable material for the flex tube (Denoted in diagram 6.5.3.) has not been developed. The material would have to be thin, strong and able to withstand extreme heat and cold. There are materials available at this time that would meet these requirements, but they tend to break down under the radiation that they would be exposed to in space. For this reason the flex tube would take more man hours to develope.

If extensive development of a new material is required, the cost would also increase compared to other more readily applied methods that do not need any further development.

2. If the flex tube has limited retractability, depending on the on the structure of the outer walls, micro G experiments could be inhibited if the station had limited fuel for slowing down of rotation.

The advantages to this method are:

1. Most of the system is enclosed. For this reason maintenance to the system would be safer and less costly. There would be less need for EVA during repair of equipment.

2. The need for elevator maintenance would be eliminated or cut down drastically. This is dependent on the system chosen for the flex tube. (The systems are denoted in diagrams 6.5.3 - 6.5.3d.)

3. The extreme ease of maintenance as compared to most other designs would make it more cost effective and much safer for inhabitants in the long run. This method will be more costly in the short term due to additional development costs caused by the development of the flex tube.

Section 06.5.4

Alternate Method of Meeting Mission Requirements

This design uses a rotating airtight seal. It is exactly the same as the design discussed in section 6.5.2, but there is no transfer module and no are locks between the elevator docking module and the center capsule, as shown in diagram 6.5.4. People and cargo need not go through an airlock to reach the elevator docking module. All other parts to this design work the same as the design in section 6.5.2.

Section 6.5.4.1

Discussion of Alternate Method

Disadvantages to this method are:

There is no information available on rotation airtight seals. There cost, effectiveness and durability are not known.

This is assumed to be difficult so the cost of developing it and its effectiveness would make rotating airtight seals impractical.

Advantages to this method are:

If airtight seals are readily available, inexpensive, the cost of this section of the space station could be drastically reduced.

It is noted that this design could also be implemented most other designs discussed in this chapter.

Section 06.6

Discussion of Unresolved Issues:

The primary concern with designs that use elevators to move from the center capsule to the outer capsules is how to deal with a jammed elevator. This could be caused by a meteoroid hitting the elevator or the elevator control winches failing in between capsules. Since EVA is considered dangerous, and by the inspection of the nature of EVA in a rotating environment, there would be no reasonably safe way to get passengers in the elevator to safety. This is despite EVA suits in the elevator modules.

A plan for dealing with this situation effectively is needed. Several possible solutions have been proposed.

They are:

1. Attach hitches, similar to the hitches used for repelling of cliffs, to the EVA suits to allow passengers to repel to an outer capsule.

This would require installing pressurization entrance chambers in both of the outer capsules and would take up large amounts of space in them. Also, because of the weight of an EVA suit, a more effective breaking device would have to be developed to keep people from sliding uncontrolled into the outer capsules.

2. Despin the station and dock a shuttle to the elevator. Shuttles will seldom be available on short notice. This would not allow enough time to get persons out before running out of oxygen.

3. Do not use elevators.

The elevator concept, at this time, is the most practical method of getting from the center capsule to the outer capsules and back.

The alternative to the elevator (represented in diagrams 6.5.3 - 6.5.3d) at this time is impractical. The material used for the flex tube would have to be radiation resistant, reasonably puncture resistant, extremely thin, and extremely light weight. Until a suitable material is found for the flex tube this design could not be implemented.

Another unresolved issue it the spinning air tight seal. There is no material available on this subject through either the NASA data base (Or at least that I am classified to see.), or on any of the University Library reference or data base systems. If a spinning air tight seal was easily maintained and cost effective, the design for this elevator could be greatly simplified. This could cut the cost and weight of the system by as much as one - third.

Section 06.7

Summary:

Again as mentioned in section 6.5, basically all designs can be grouped together and interchanged. Using an elevator is the most effective way to move from the center module to the outer modules. All elevator designs are just modest extensions of present technology, therefore more cost effective.

As for individual elevator designs, the fixed elevator was favored over the crawling elevator because wear due to slippage would be eliminated. Also, the fixed elevator, because it is fixed to the elevator cables, is less likely to be separated from the elevator cables during operation.

The last main part, the configuration of the end of the center module, of the three different designs, the configuration of the center capsule and the elevator docking module in section 6.4 was chosen as the most practical. This system has only one piece, and is extremely light weight. It also saves on center capsule space. Its principle flaw is that it could be disabled the easiest. If the magnetic ring or elevator docking module is struck by a projectile, the entire station could be disabled. The shuttle would be unable to dock because the center capsule would be spinning with the outer capsules. The station would have to be despun to enable access for repairs.

From the information available for this report, at this time, the design represented in section 6.4 would be the safest, most cost effective and easiest to implement.

Section 06.8

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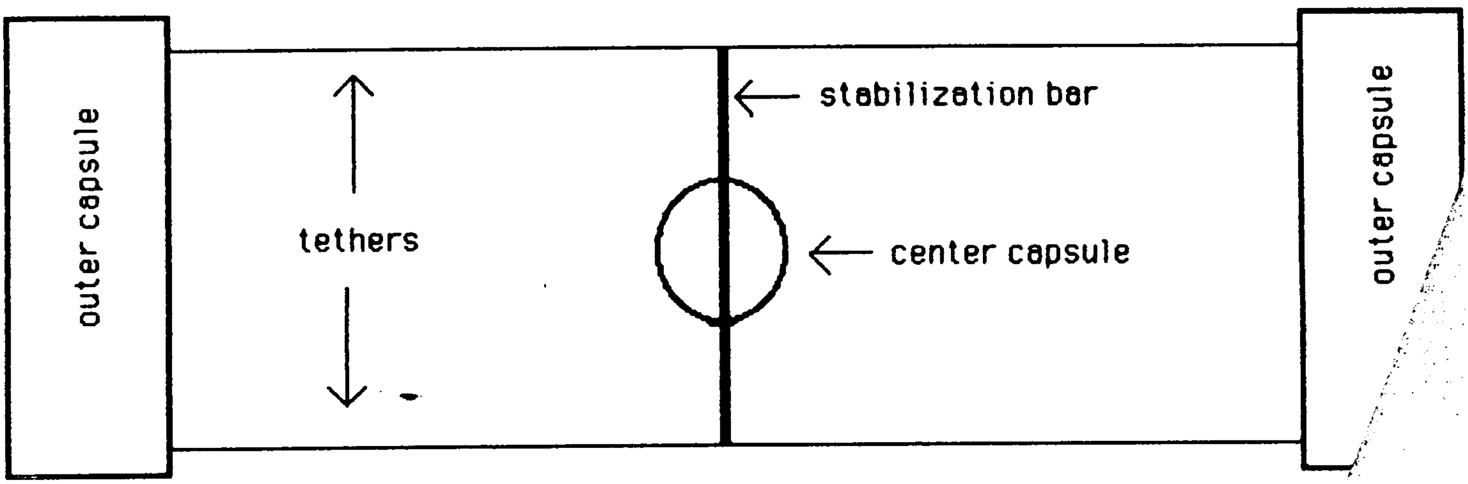
060010 Parker, D. 1987. Assistant Chairman, Space Studies Dept. University of North Dakota. Personal interviews.

Diagram 6.1a

The Variable Gravity facility

All elevator designs are based on the design of the variable gravity station below.

top view



side view

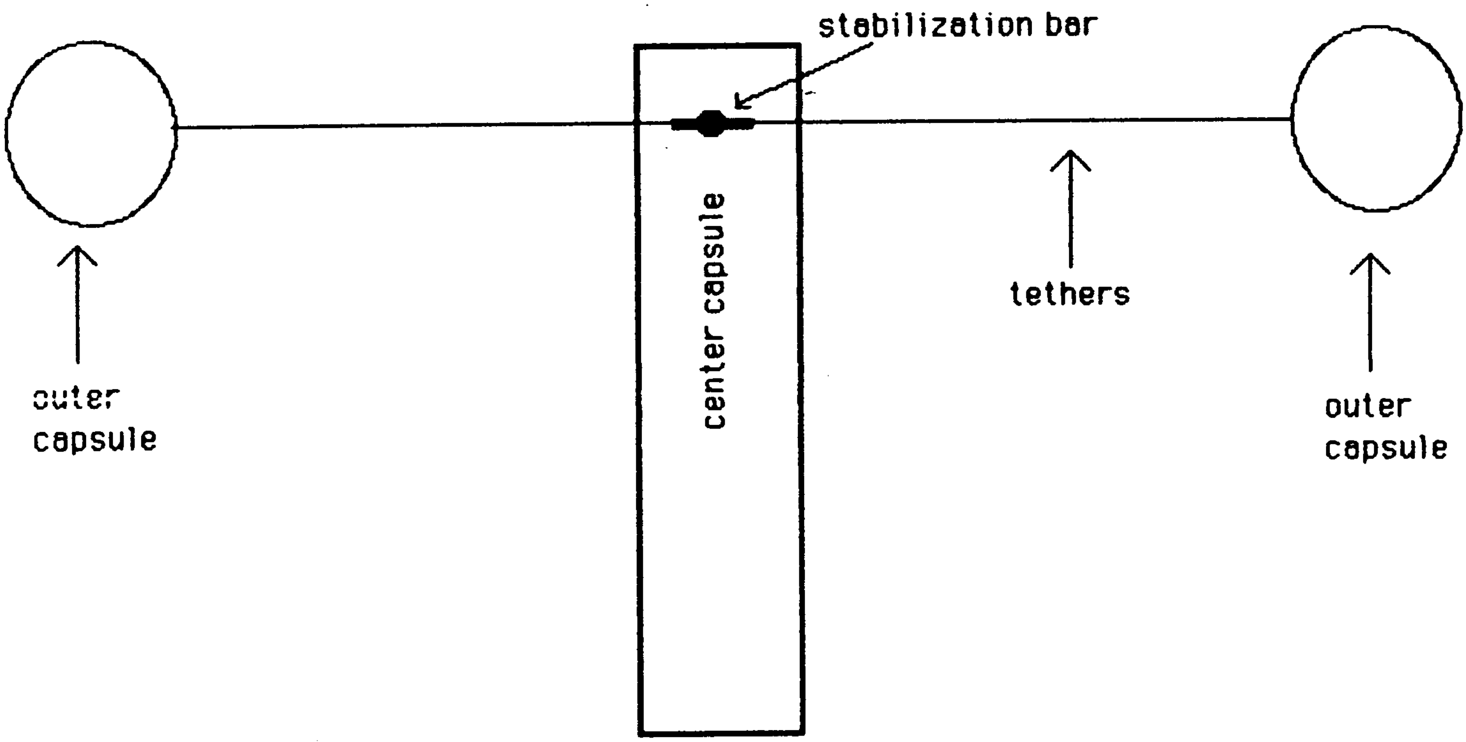


Diagram 6.4

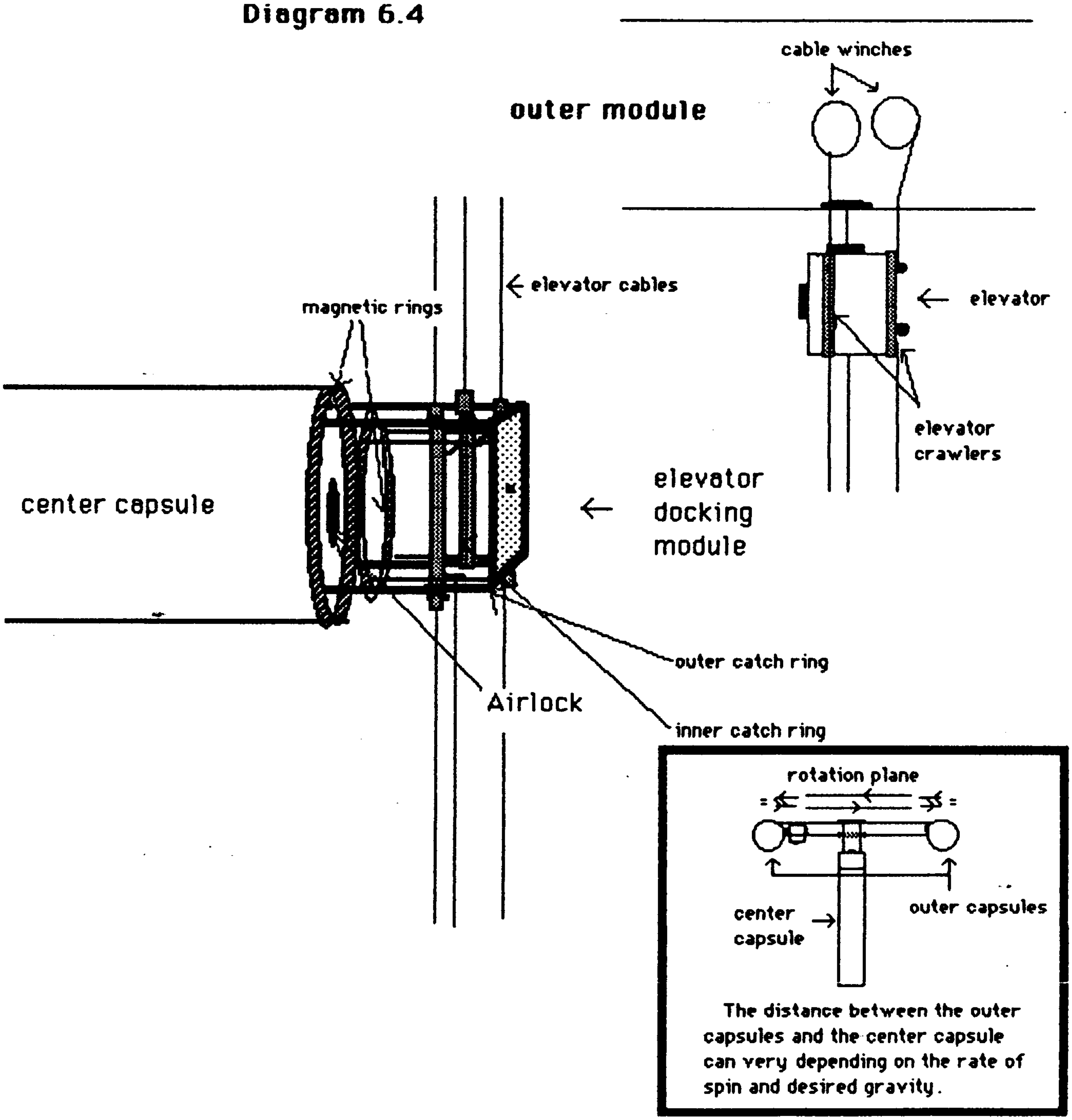
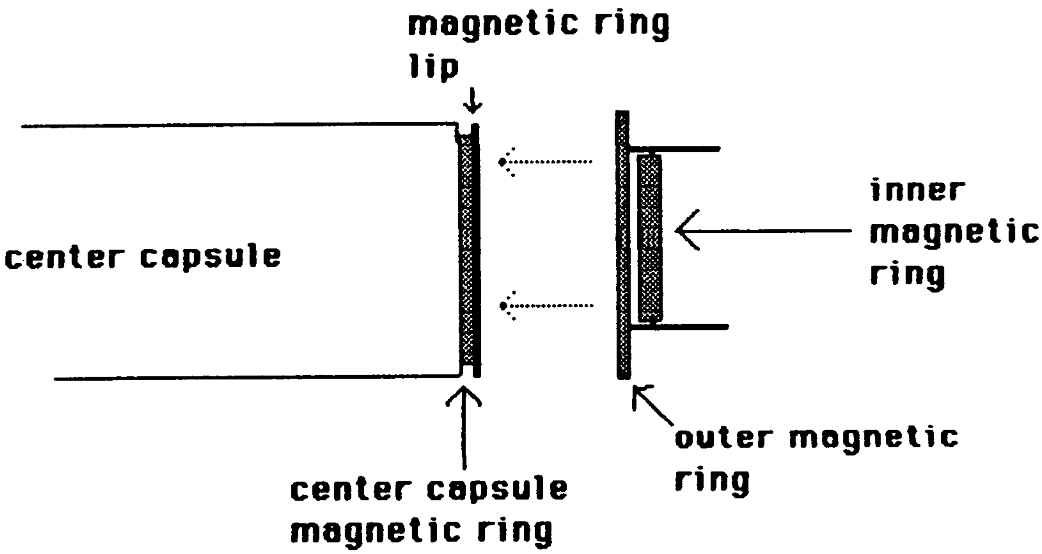

cable winches
outer module
elevator cables
magnetic rings
elevator
elevator crawlers
center capsule
elevator
docking
module
outer catch ring
Airlock
inner catch ring
rotation plane
center
capsule
outer capsules
The distance between the outer capsules and the center capsule can very depending on the rate of spin and desired gravity.

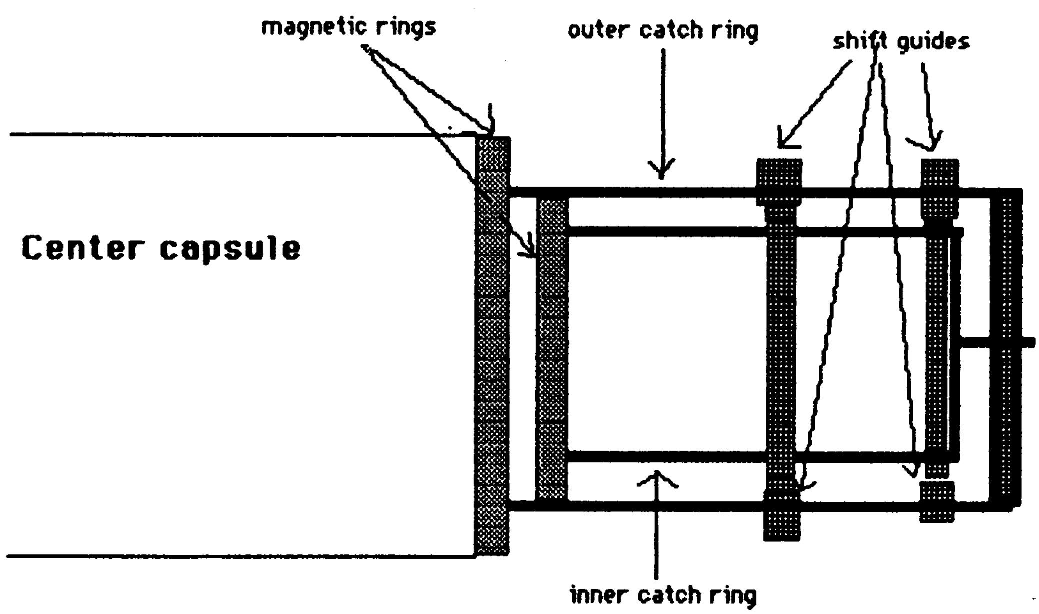
Diagram 6.4a

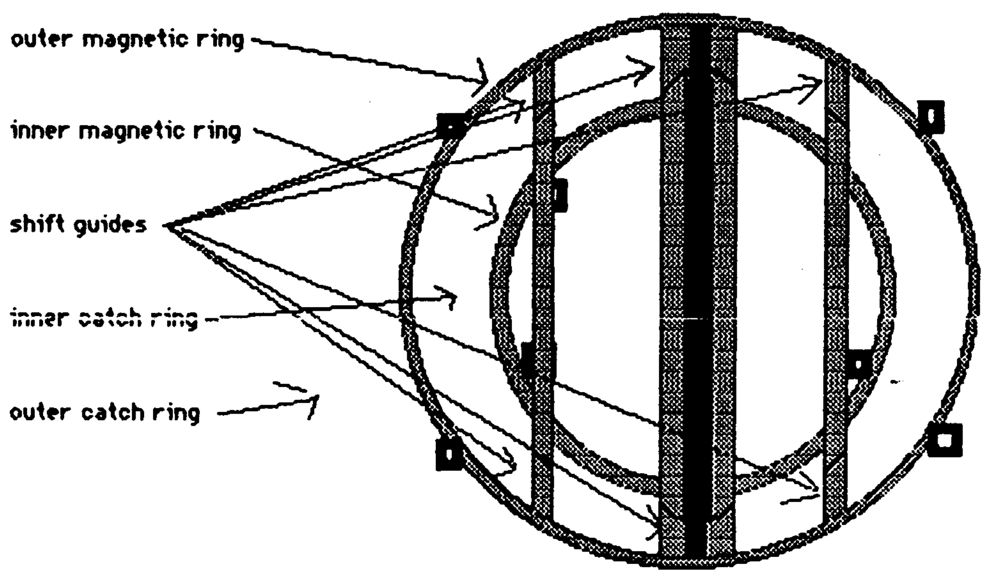


The outer magnetic ring is removed from the center capsule magnetic ring in this diagram.

Diagram 6.4b

The Elevator Docking Module





view of the elevator docking module from the center capsule side

Diagram 6.4c

The Outer Catch Ring

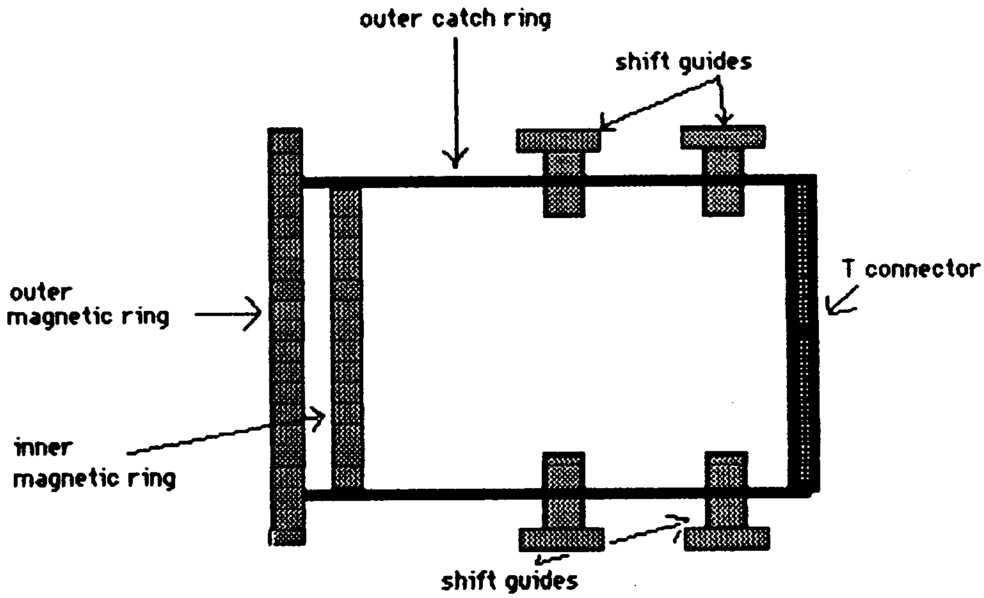
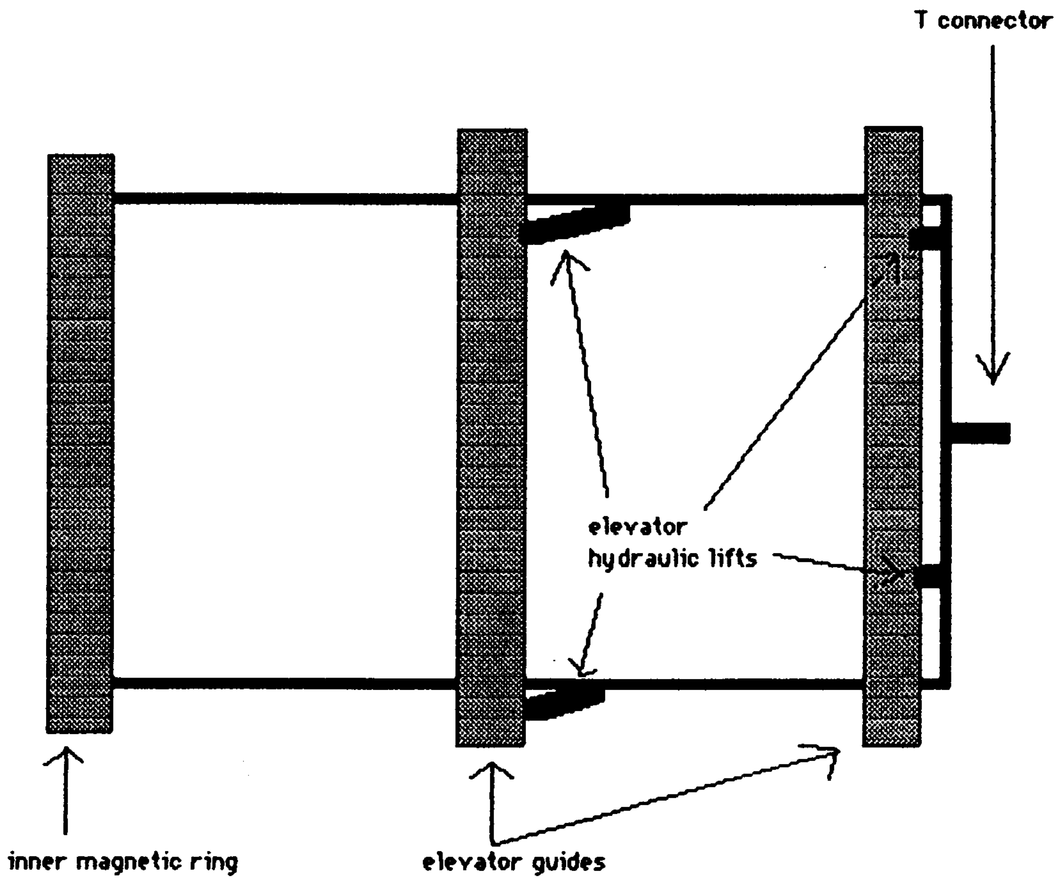


Diagram 6.4d

The Inner Catch Ring



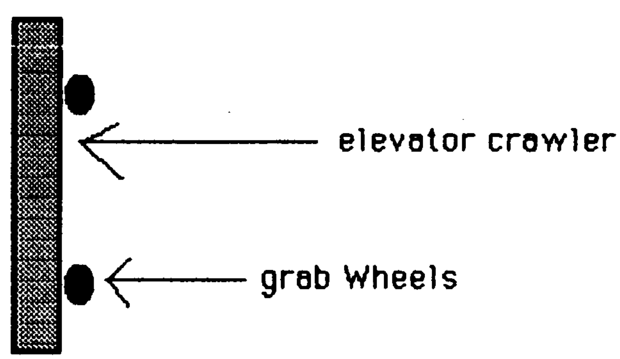


Diagram 6.4e

The Elevator

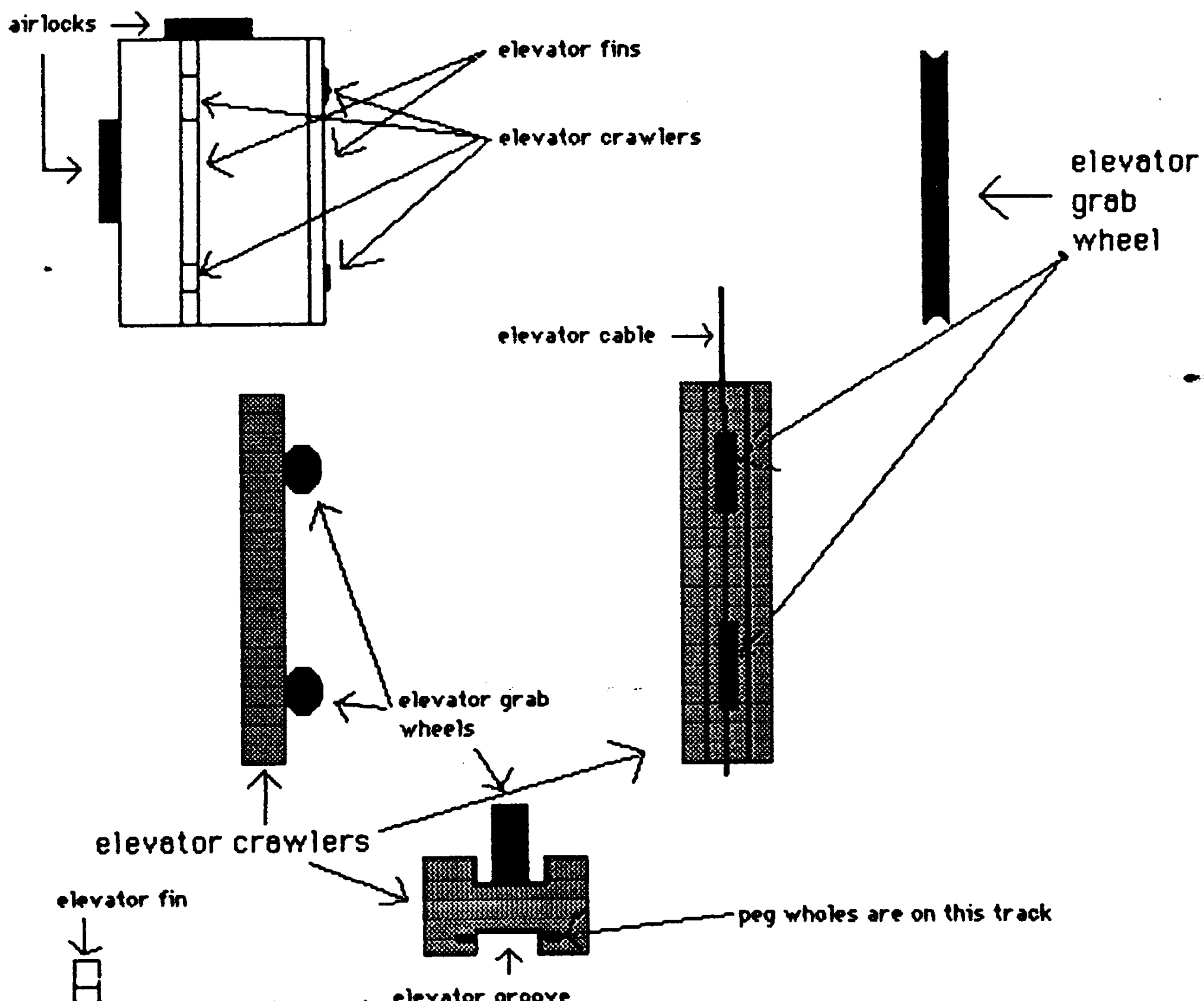


Diagram 6.4f

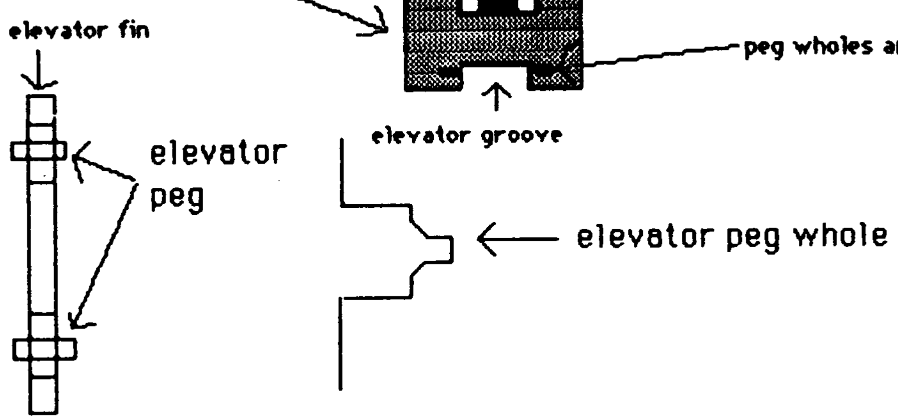


Diagram 6.4g

The Elevator Cable Winches

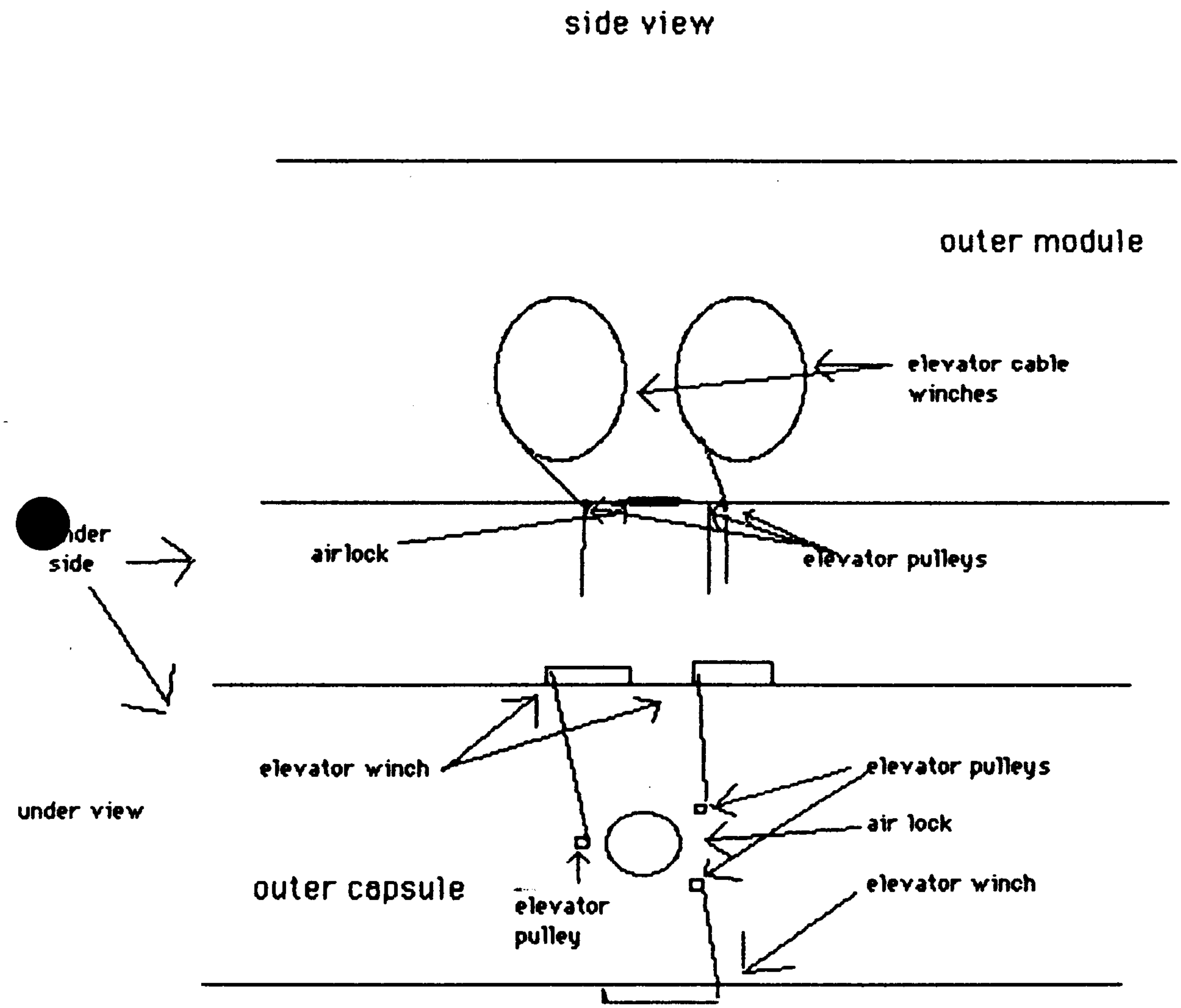


Diagram 06.5.1a

Alternate Method of Meeting Mission Requirements

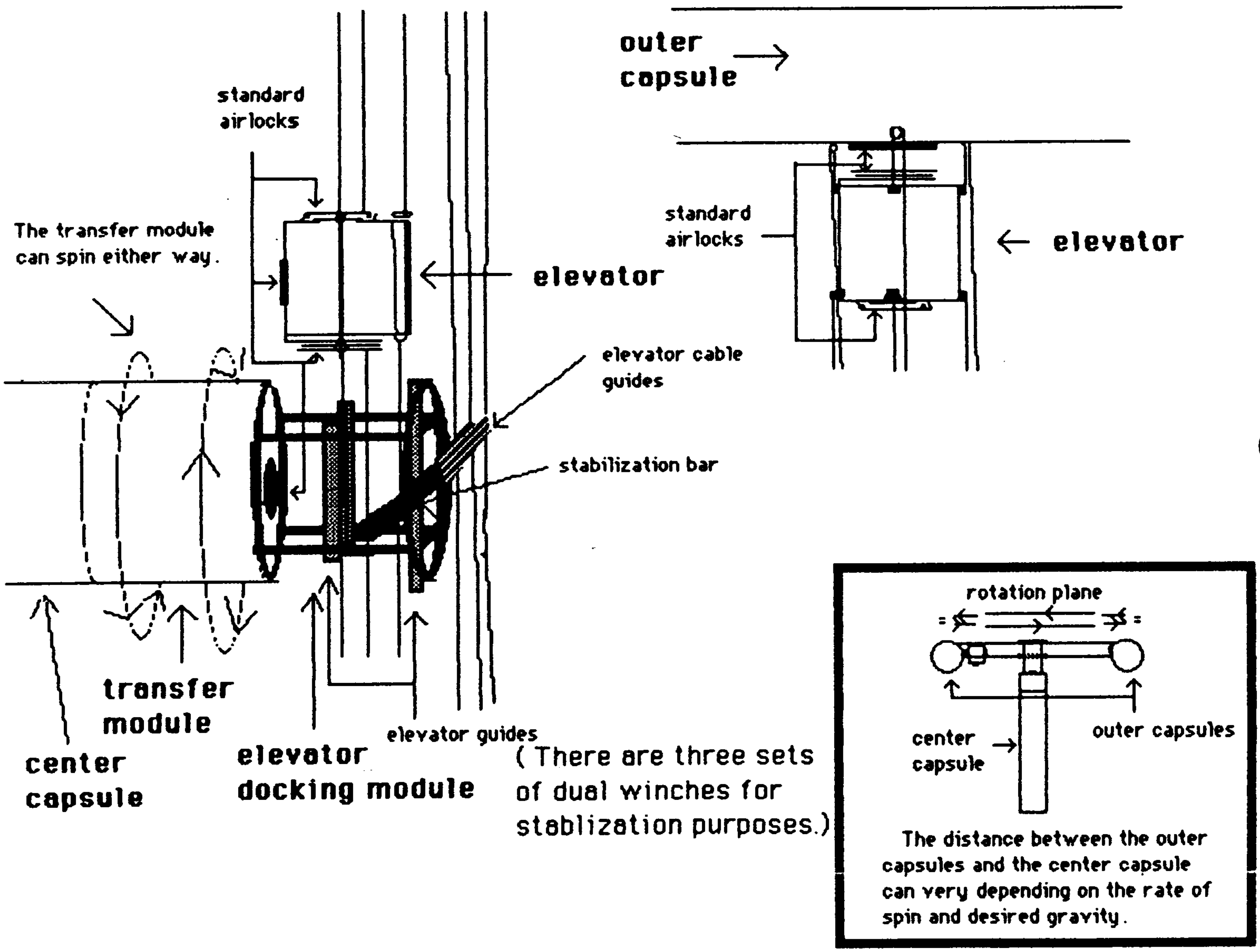
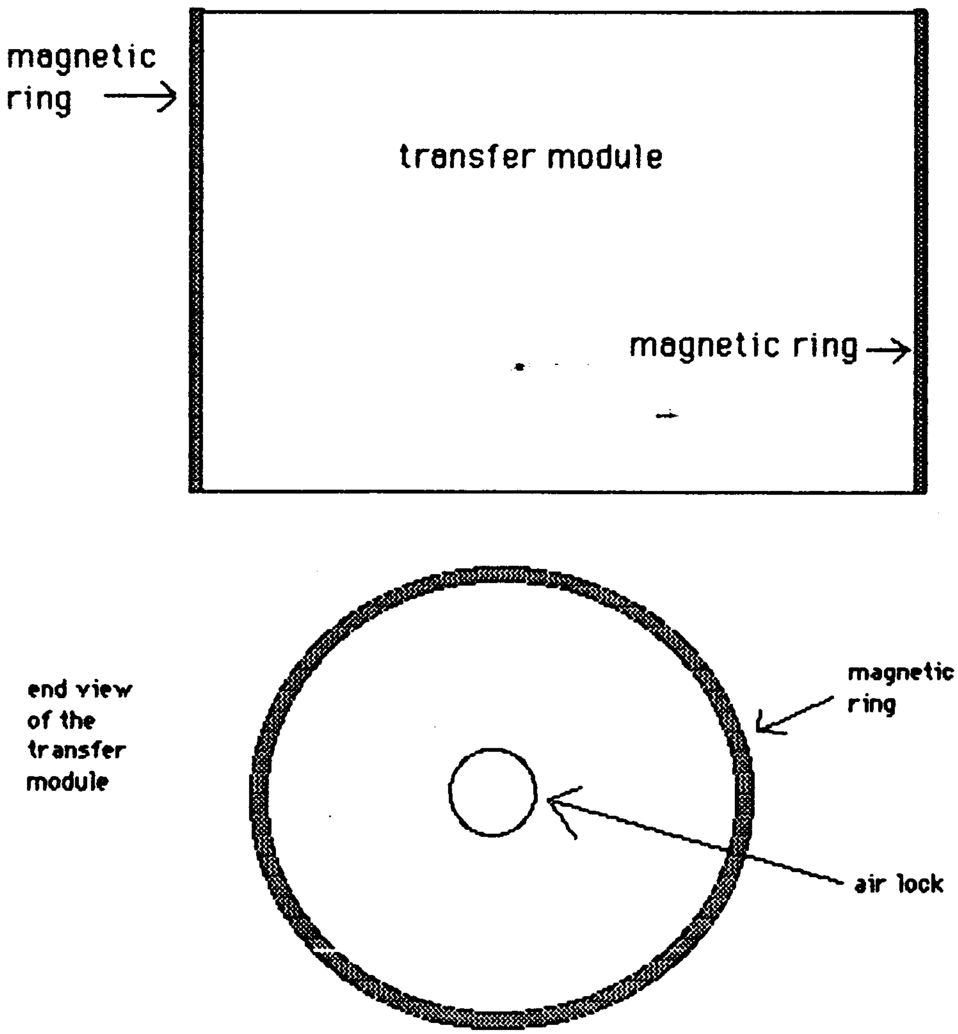
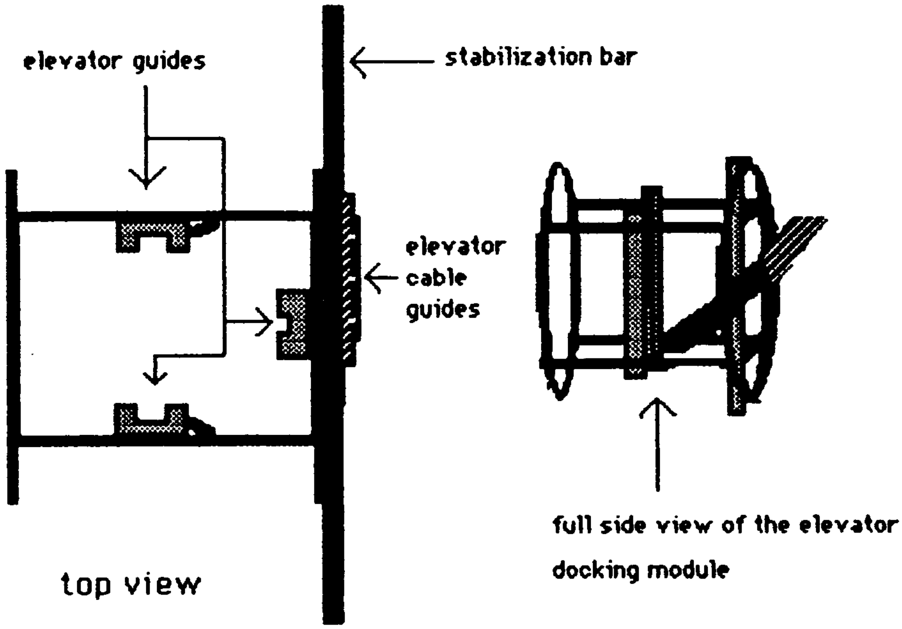


Diagram 6.5.1b

The Transfer Module



Diagrams 6.5.1c and 6.5.1d



The Elevator Guides

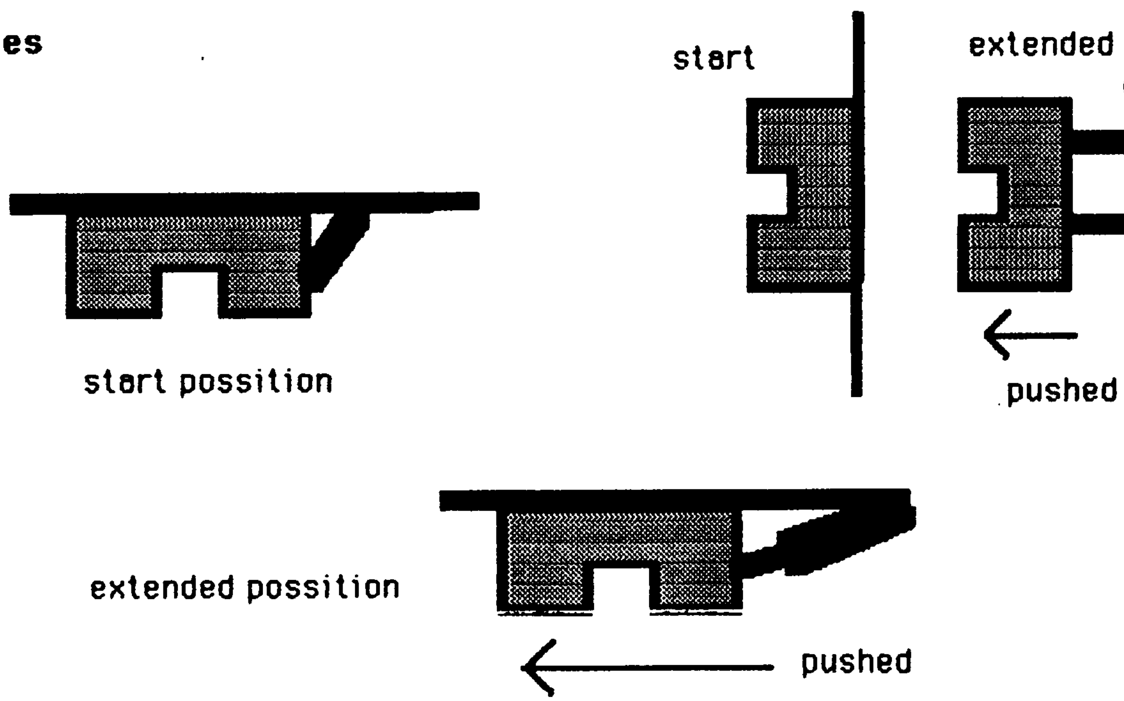
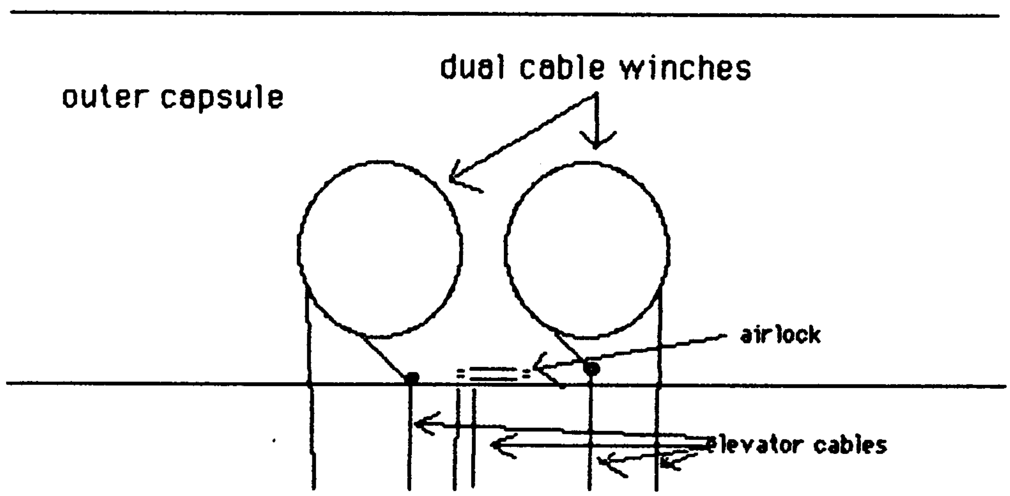


Diagram 6.5.1e

The Dual Elevator Cable Winches



side view
of a stacked
dual elevator
winch

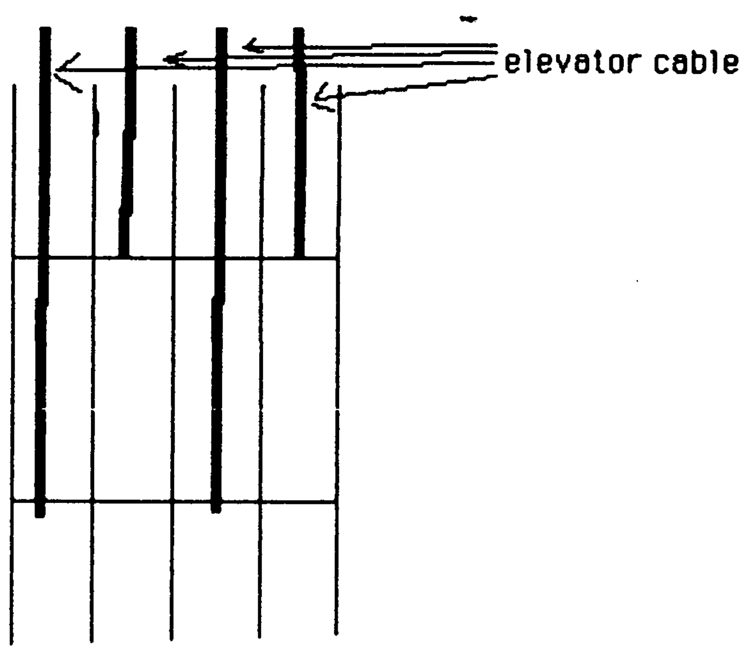
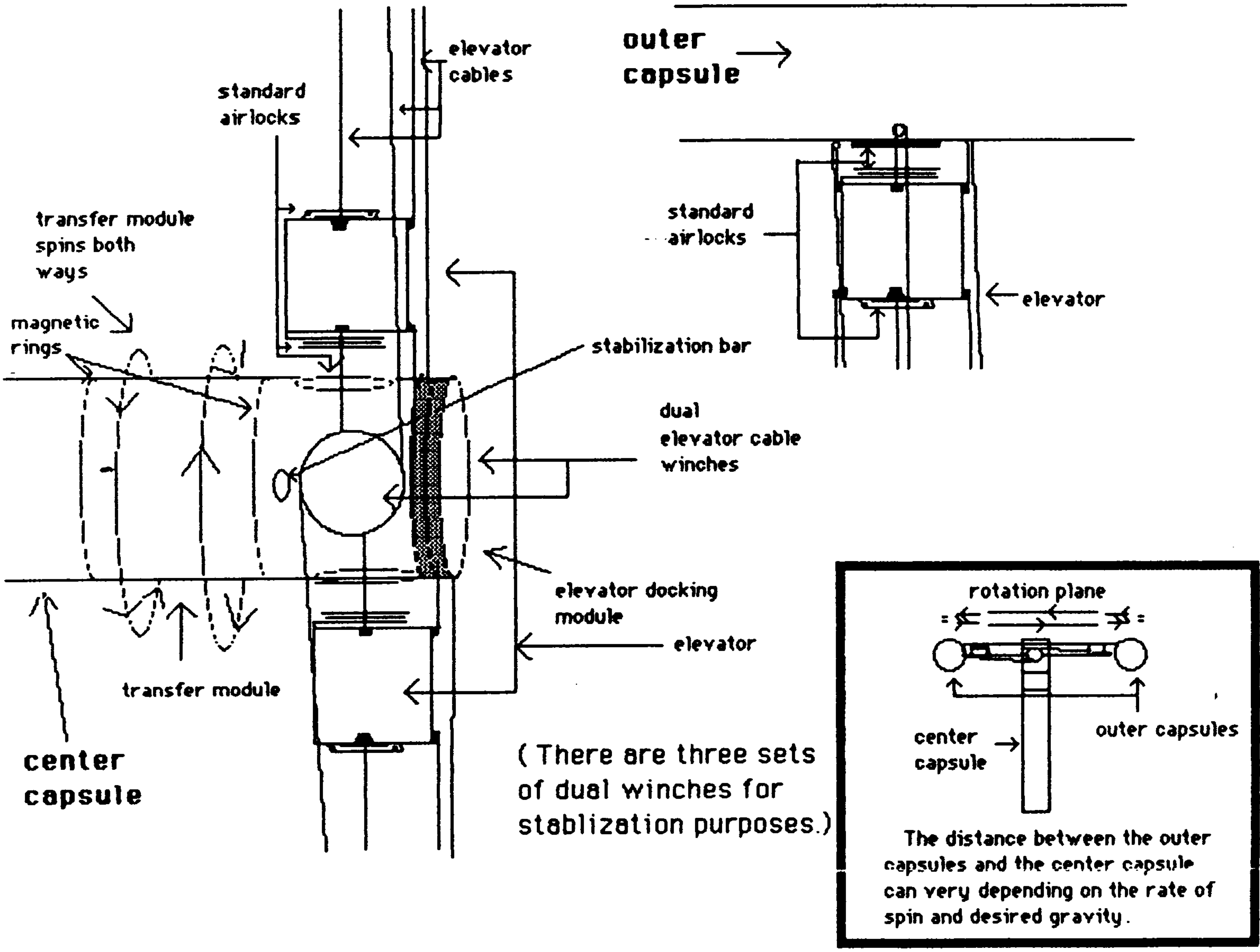


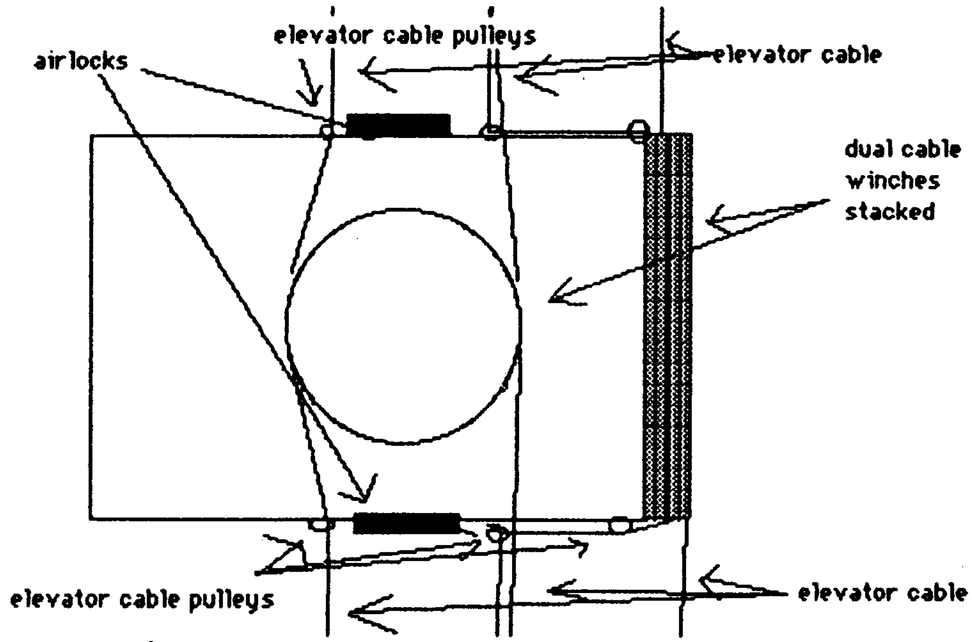
Diagram 06.5.2a

Alternate Method of meeting Mission Requirements.



Diagrams 6.5.2b and 6.5.2c

The Elevator Docking Module



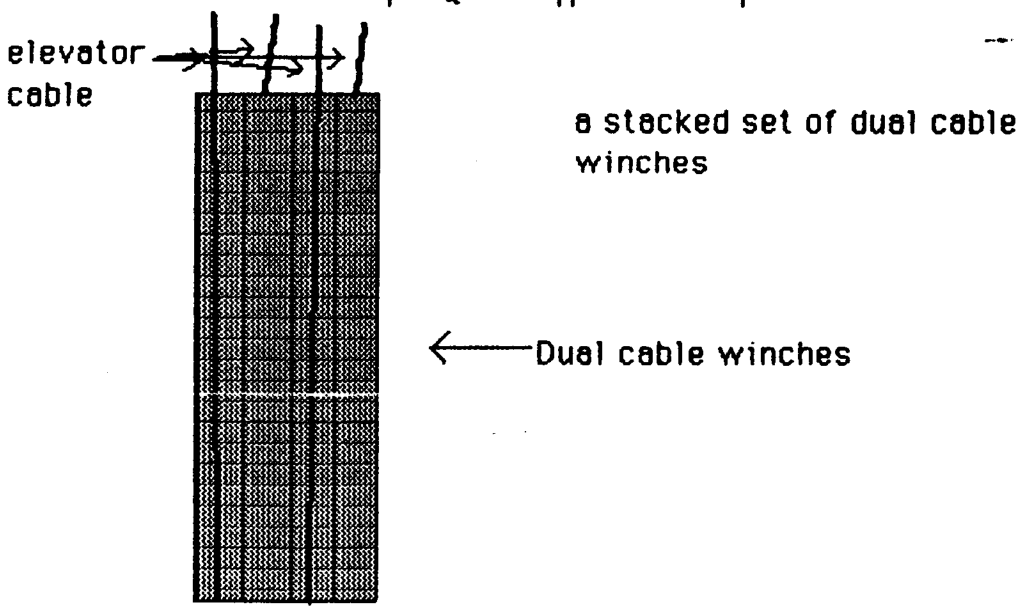


Diagram 6.5.3

Alternate method of Meeting Mission Requirements.

Diagram 6.5.3b

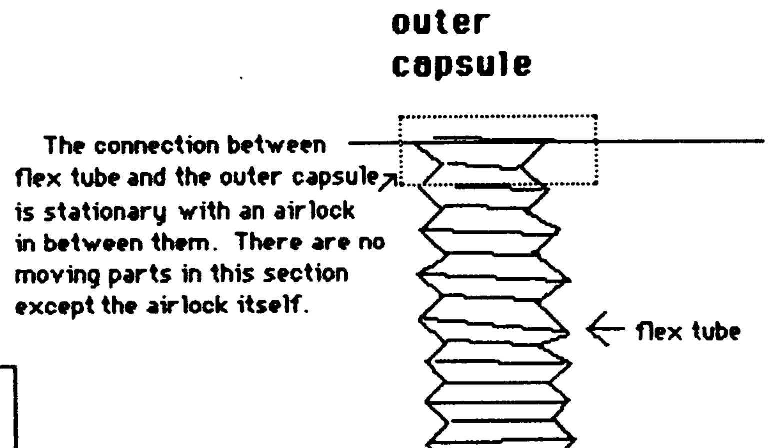
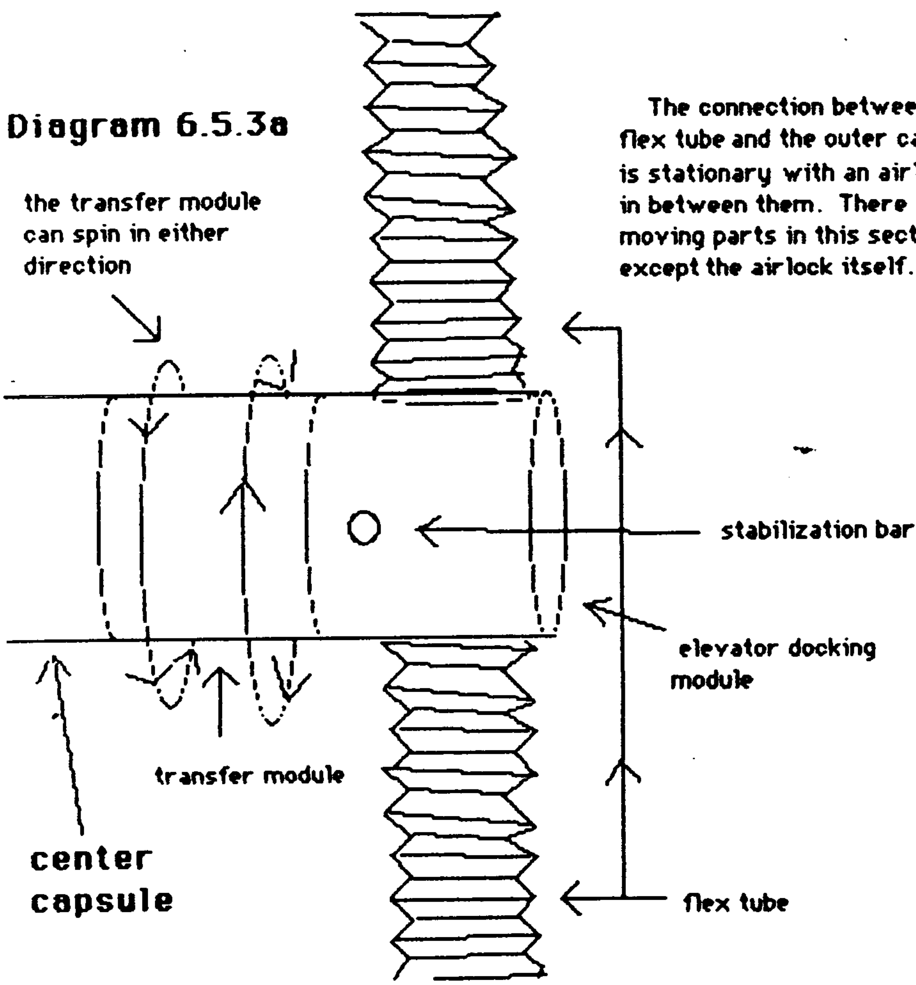


Diagram 6.5.3a



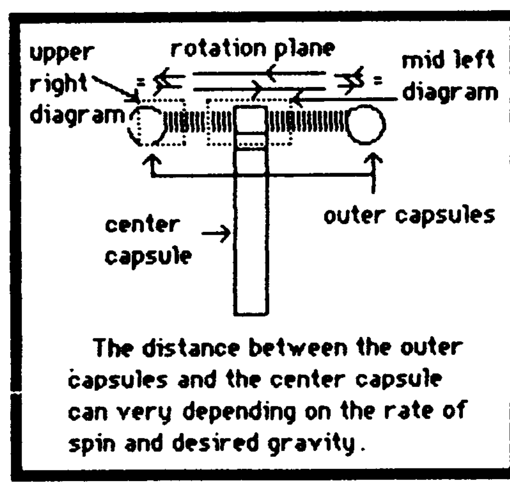
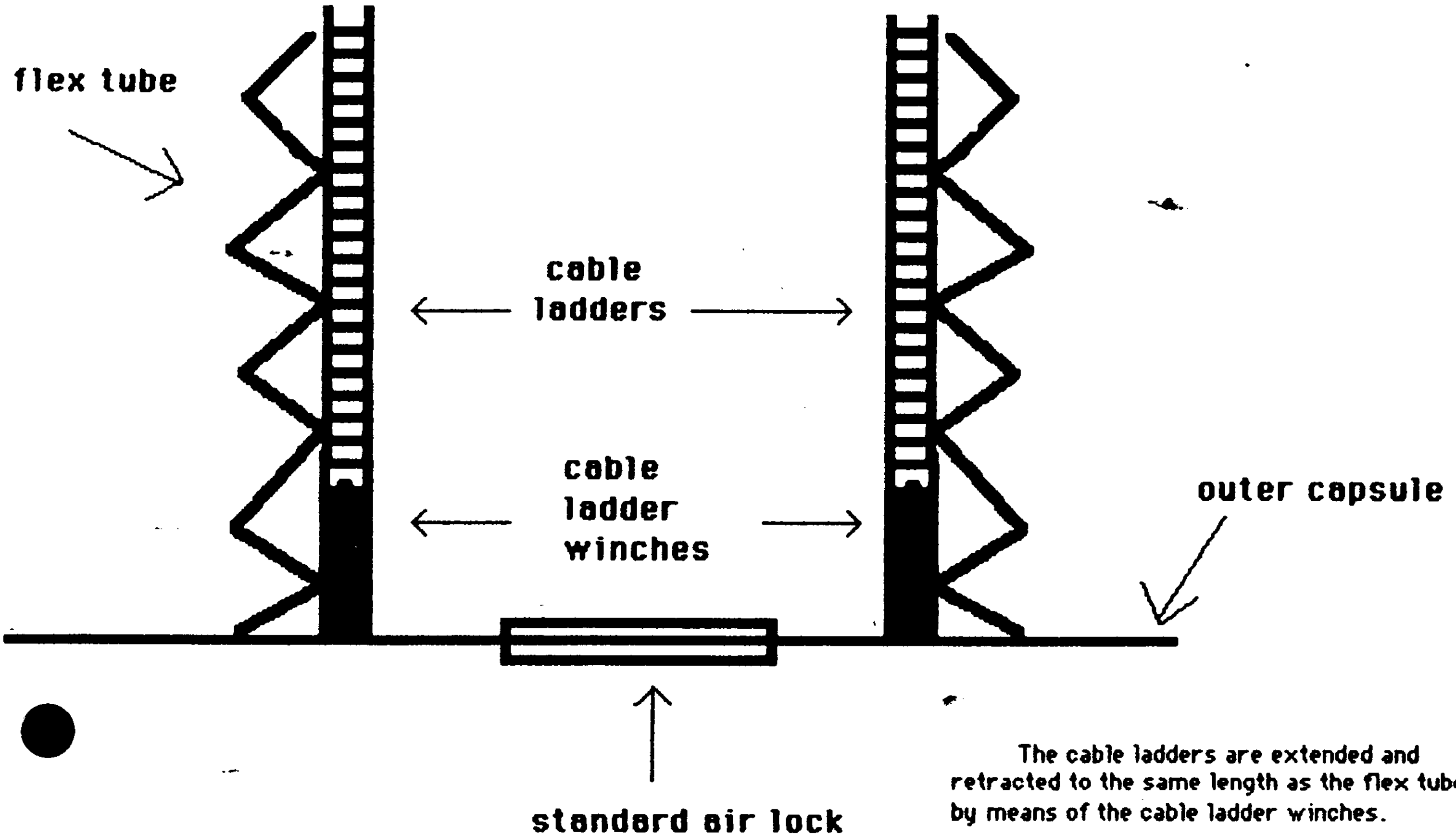
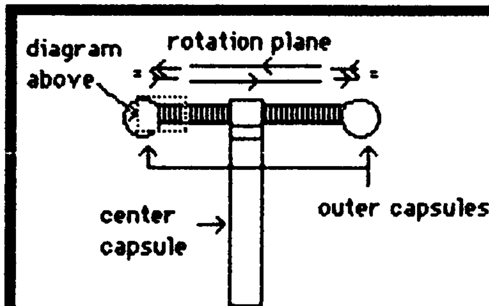


Diagram 6.5.3c

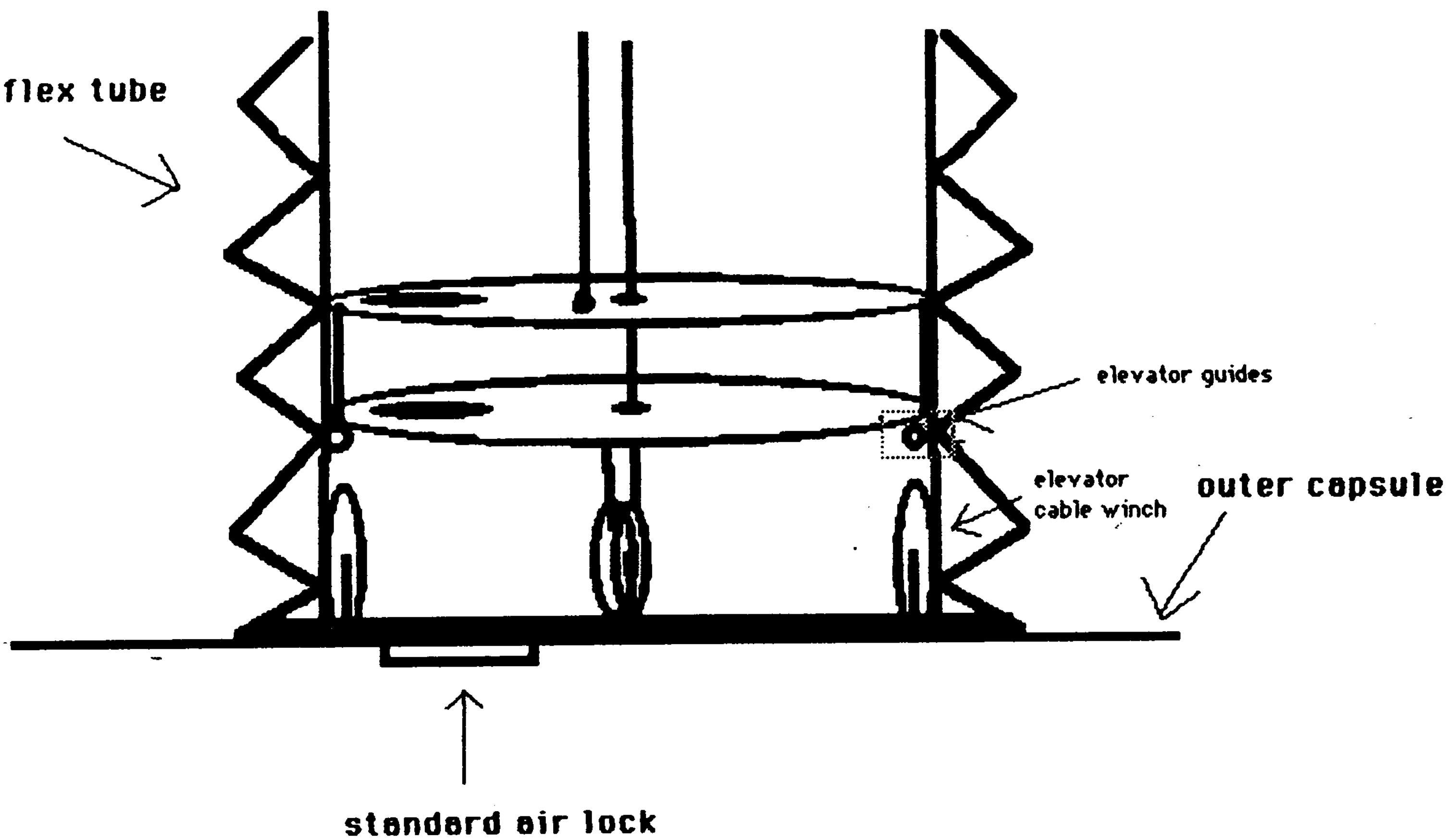


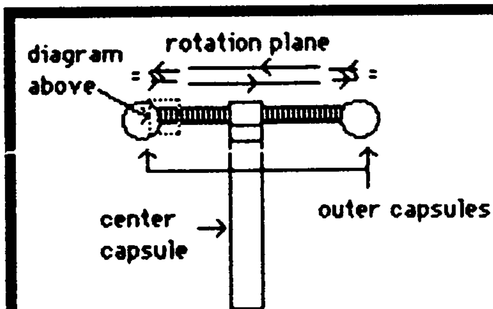
The cable ladders are extended and retracted to the same length as the flex tube by means of the cable ladder winches.



The distance between the outer capsules and the center capsule can very depending on the rate of spin and desired gravity.

Diagram 6.5.3d

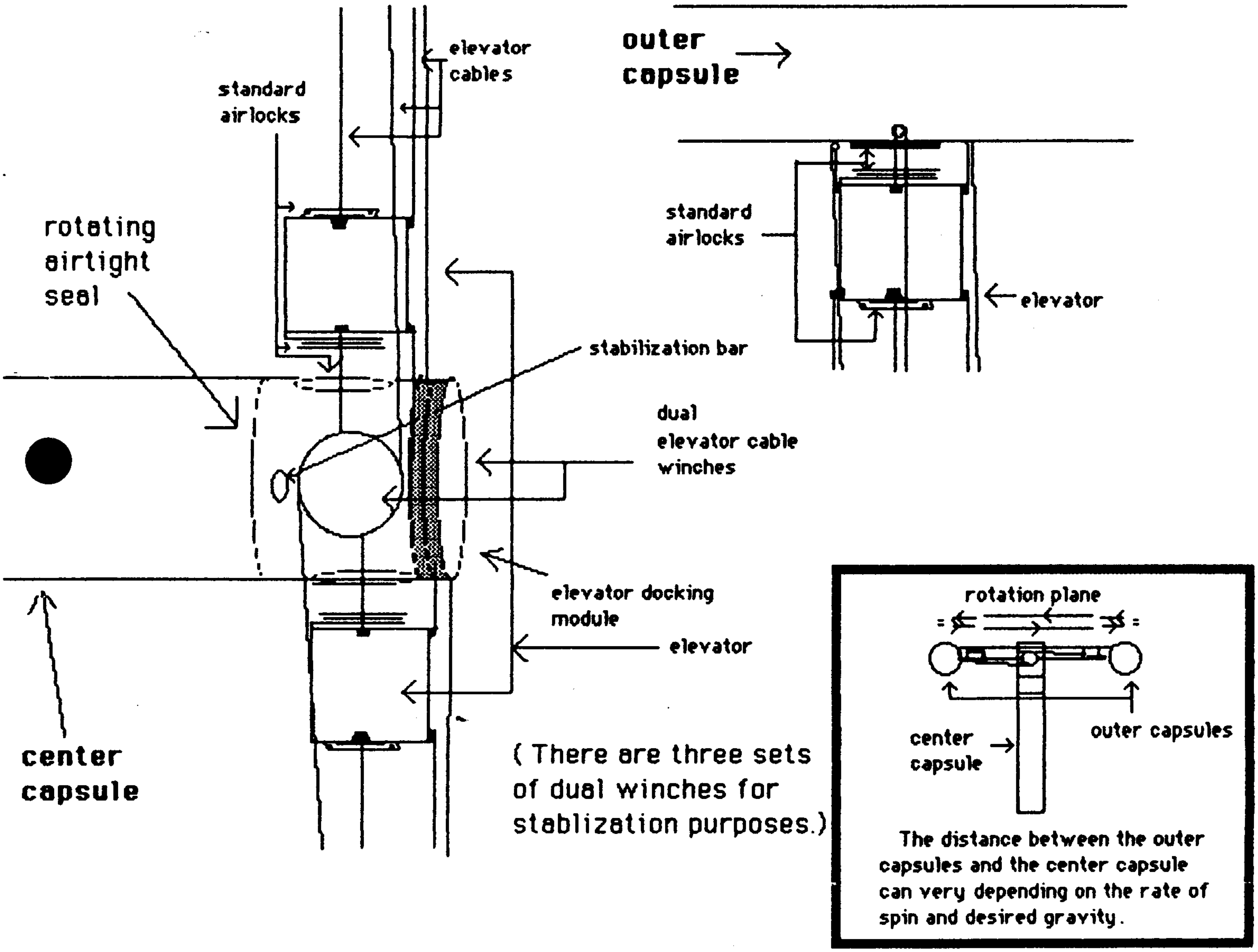




The distance between the outer capsules and the center capsule can very depending on the rate of spin and desired gravity.

Diagram 06.5.4

Alternate Method of meeting Mission Requirements.



This design uses a rotating airtight seal instead of making the center capsule and the docking module two different airtight modules.

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CHAPTER 7

Elevators for a Variable Gravity Facility

by

Mark G. Eagon & Anthony C. Lamo

7.1 Definition of Topic

A variable gravity facility (VGF) elevator is required to transport passengers and equipment between modules of a (VGF) space station. An elevator is any system that accomplishes this task.

7.2 Backround Information and Assumptions

A (VGF) will consist of two rotating living modules tethered to a despun inner module that will be used for docking and storage. An elevator will be necessary to transport human occupants, equipment, and possibly fuel between the modules. It must be able to convert between a despun state and a rotating environment. It will have to be large enough to fit personnel comfortably but must also meet space shuttle loading requirements.

7.3 Proposed Mission Requirements

The system will need to be driven in a simple matter to cut down on cost, weight, and maintainence. It can be as wide as a standard space station module. It should be airtight and pressurized to allow for a "shirtsleeve" environment.

7.4 Proposed Method of Meeting Mission Requirements

7.4.1 Primary Plan

Refer to Figure 7.A. A decoupler will be attached to each cable independently (1) and brakes will be utilized on the guide wheels (2). The elevators will be repressurized each time they dock, making use of established life support mechanisms inside each module and at the same time increasing elevator capacity while decreasing cost and maintainence. For safety, emergency space bubbles will be placed inside the elevators and crew members trained on their use periodically. If for any reason the elevator loses its drive capability, an emergency winch and brake can also be provided.

The VGF should use the rotational motion of the station and its own artificial gravity to move between docking stations. There will need to be a dual elevator system to counteract the change in forces created by adding and subtracting weights in rotating body. It will need to be at least 2.5 meters long and at least 2 meters

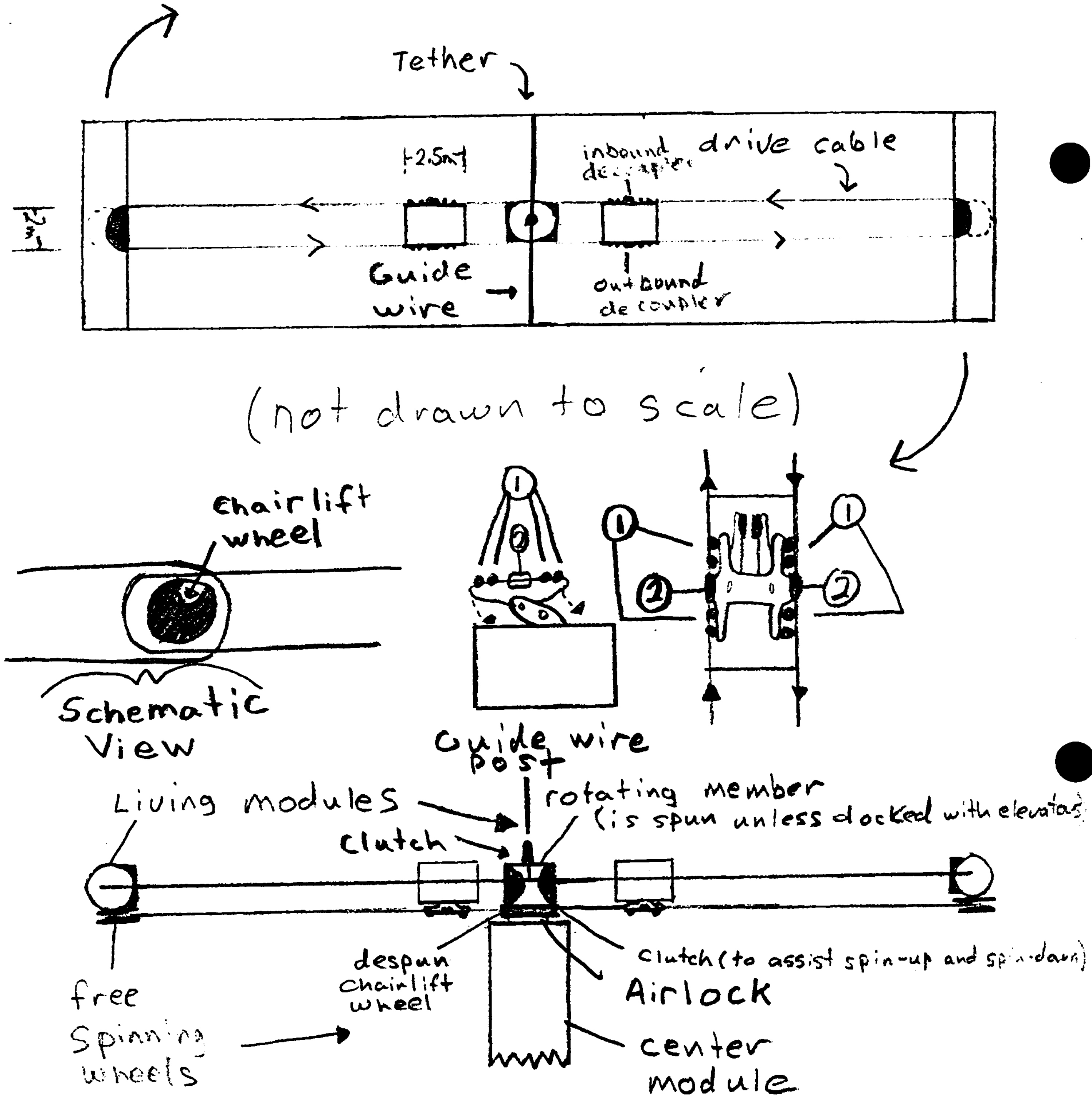

Tether
2.5m
inbound decoupler
drive cable
Guide wire
outbound decoupler
(not drawn to scale)
Chairlift wheel
Schematic View
Guide wire post
Living modules
rotating member (is spun unless docked with elevators)
clutch
despun chairlift wheel
Clutch (to assist spin-up and spin-down)
Airlock
free spinning wheels
center module

FIGURE 7.A

wide for comfort and economy.

The main idea for driving the elevators is based on technology over 50 years old. It is based on a common ski chairlift with a few modifications similar to a tramway system used to elevate up mountains. A center "chairlift wheel" is attached to the despun center module. Two opposed cable loops that connect the living modules are held firmly about the wheel by centripetal force. The cables are firmly grabbed by the wheel due to friction, thus, cycling the cables around it and the outer wheels connected to the living modules, when the station is in its usual rotating state. (Refer to Figure 7.A and 7.B) A clockwise VGF rotation will cause a counter-clockwise elevator cable rotation. To collect the elevators to the middle, simply attach the inbound decoupler to the inbound cable. The elevator will draw to the middle. Upon arrival, the elevator is decoupled from the cable and docks with the rotating member. The decoupler unit is then pulled in for cable clearence and a clutch is engaged to despin the rotating member, as well as, the two opposed elevators. An airtight door is opened at the base of the rotating member and the elevators, transfering cargo can now take place. To spin up the rotating member, simply attach a clutch located at the joint of the guide wire

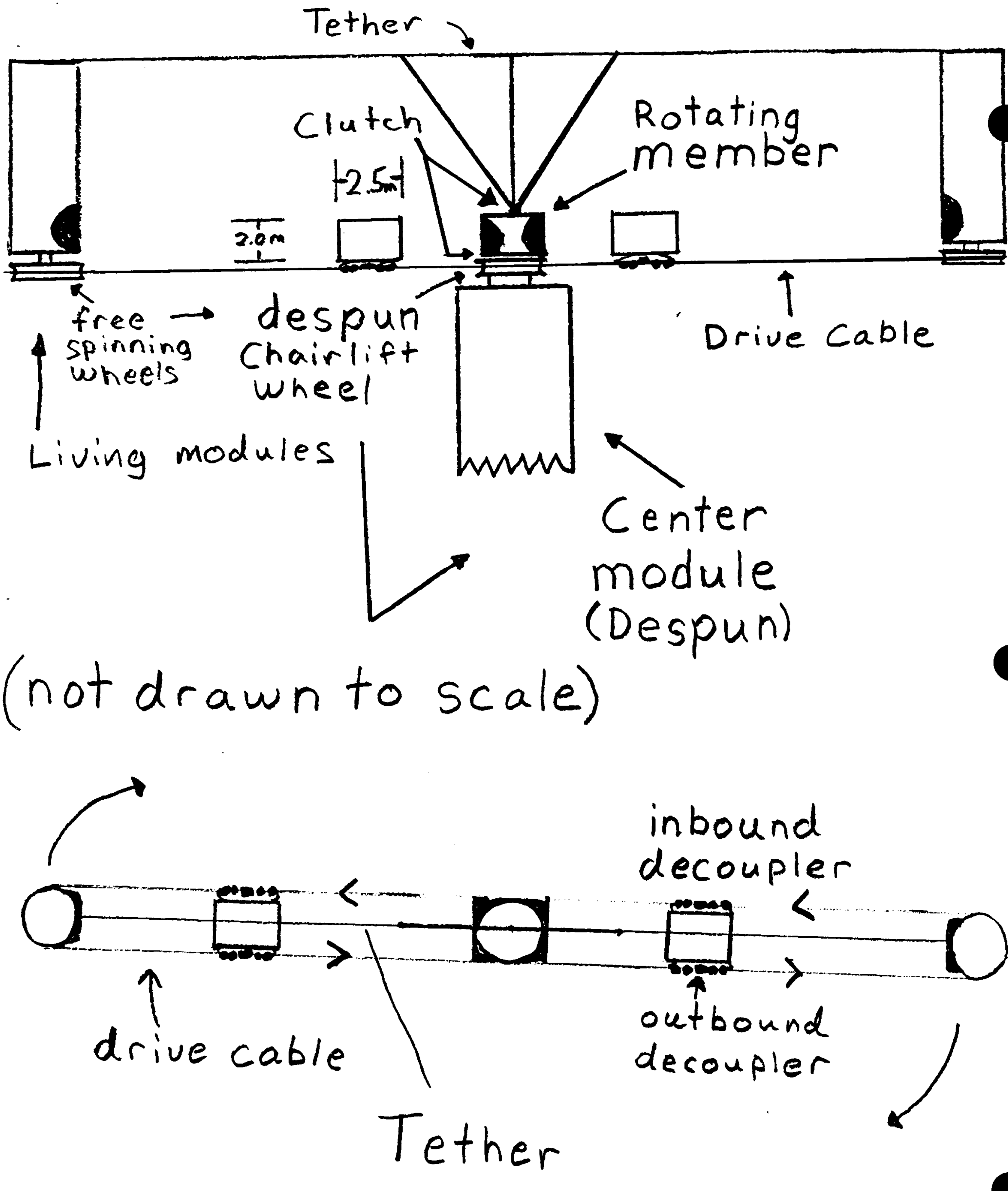
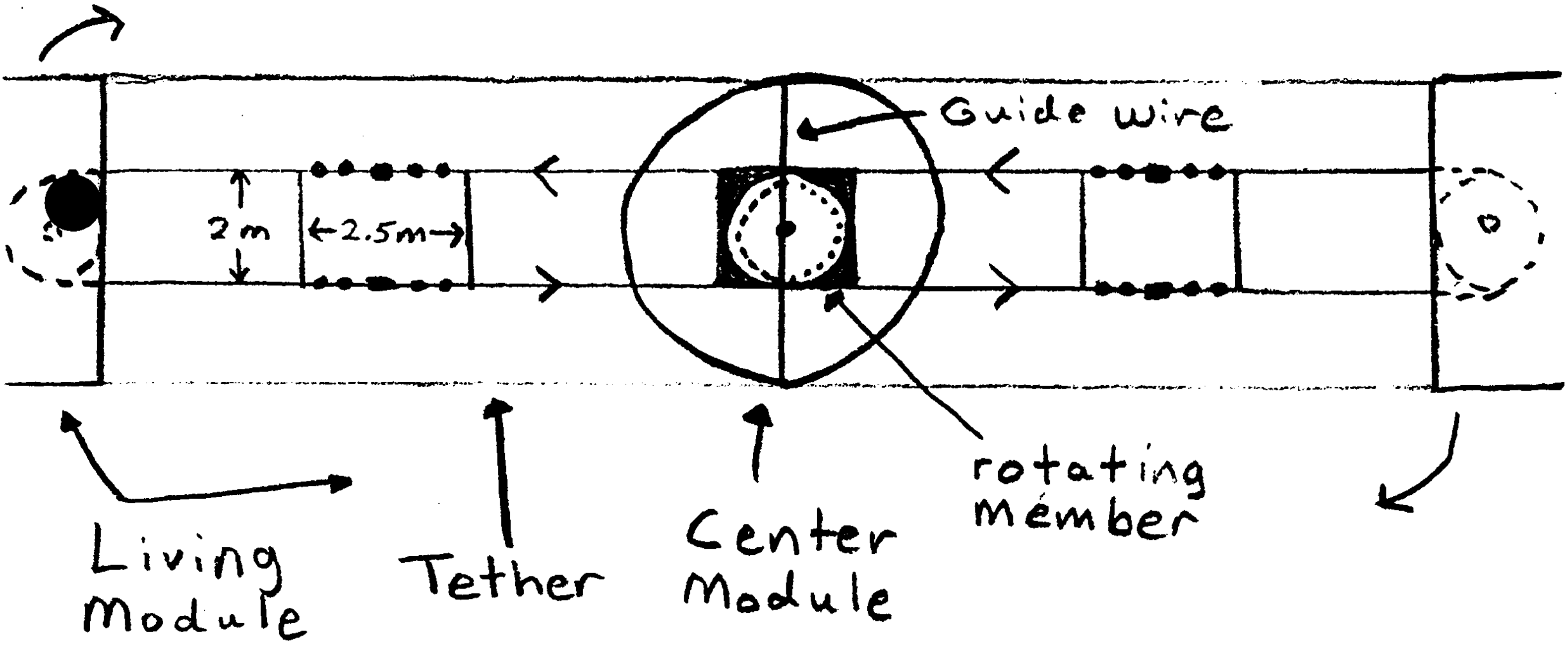

Tether
Clutch
Rotating member
2.5m
2.0m
free spinning wheels
despun Chairlift wheel
Drive Cable
Living modules
Center module (Despun)
(not drawn to scale)
inbound decoupler
outbound decoupler
drive cable
Tether

FIGURE 7.B



note: (not drawn to scale)

The Center and Living modules are made out of the external fuel tank of the Space Shuttle system.

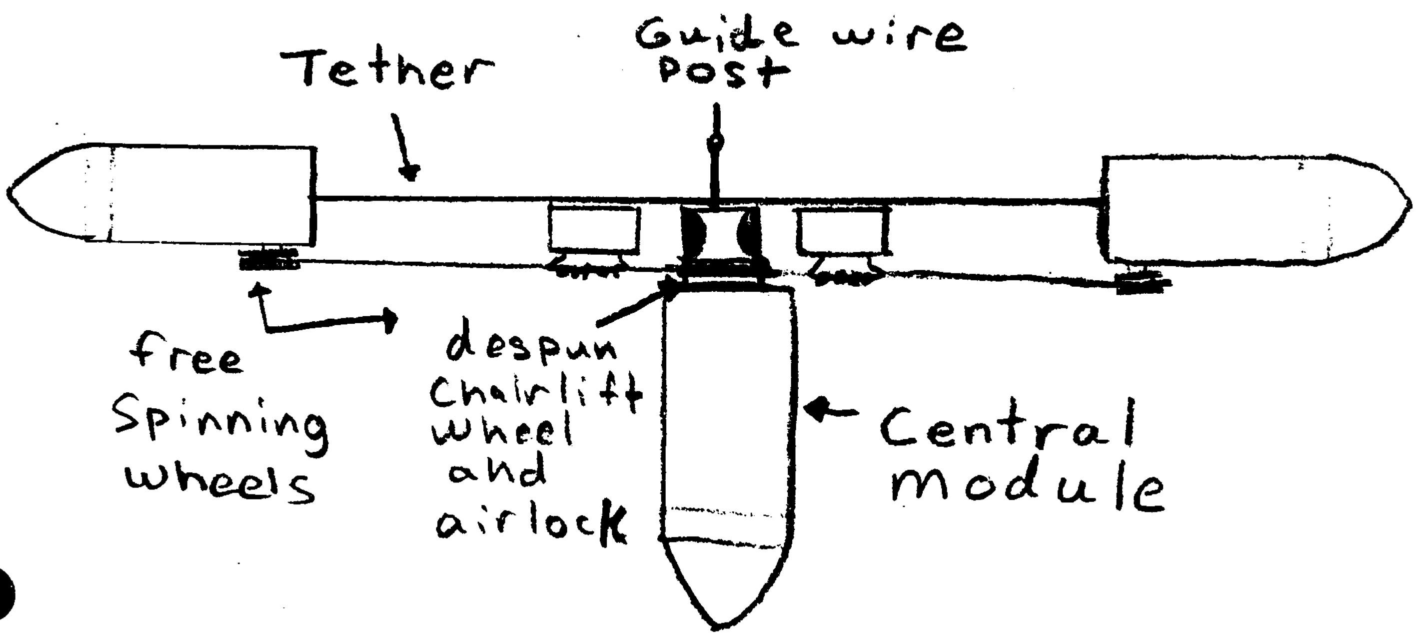


FIGURE 7.C

post (which is constantly rotating) and the entire unit will slowly spin-up. Alignment with the drive cables is achieved by computer or laser technology. When correctly positioned, the decoupler unit extends and engages the outbound cable. Docking with the living modules is substantially easier.

The air-lock located at the base of the rotating member is needed for weight and maintainence considerations. A lighter and easier to take care of joint between the rotating member and the center module can be used without worrying about making it air-tight if we include an air-lock and a clamp to be activated when the rotating member is despun. The clamp will asure an airtight seal when docking is taking place.

This system can be worked in many configurations economically. It becomes cheaper, easier, and more reliable as you go from Figure 7.A to Figure 7.B to Figure 7.C.

7.4.2 Weight Estimate of Proposed Method

The .weight of this system will vary with mission requirements, money available, and human safety factors. It was the purpose of this elevator system design to minimize cost, weight, maintainence, and human labor,

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while still keeping a shirtsleeve environment. A standard air-tight module with 100 kilograms of aluminum and plastic mechanical gear, as well as, 5 kilograms of shielding should weigh about 1500 kilograms as a minimum. The actual system will probably weigh more.

7.5 Alternate Methods of Meeting Mission Requirements

7.5.1 First Alternate Plan

There could be an elevator system similar to the one above, however, have a life support system inside the elevators to establish higher safety conditions inside them. The cost in weight, bulk, and maintainence may be prohibitive.

7.5.2 Second Alternative Plan

There could be an elevator system having its own drive system with the actuator(s) being inside the center module. This will aleviate some problems incurred by the rotational drag caused by the drive being conducted by the energy of the rotating body. The cost in weight, bulk, and maintainence may be prohibitive.

7.5.3 Third Alternative Plan

A system that uses an electrical drive system for on demand cable drive can be used. This system would incorporate a driven chairlift wheel, instead of despun, and would make using clutches, to spin the rotating member, obsolete. This system is rather complicated, would require more maintainence, and may be cost prohibitive.

7.5.4 Fourth Alternative Plan

A single elevator system may be used to reduce shipping weight and money. It could be used just like a real chairlift, as it would be permenently attached to the drive cable. An electrical drive system will more than likely need to be used. This plan falls short because of the need for rotational stability. As one elevator moves to the end of the VGF, it significantly changes the center of gravity and disturbs the orientation of spin. This would cause untold mayhem in the entire facility.

7.6 Disscussion of Unresolved Issues

The actual design of the decouplers, pulleys, brakes, and the clutch for the rotating member will have to be done by a mechanical engineer. But he will have about a 50 year head start, as this technology has been established in ski lifts for nearly that long.

Few books have been publised on space elevators and fewer still have any worthwhile facts contained in them. One mentioned consideration is the twisting of the drive cable as the elevators move to the living modules, gaining gravity until it becomes lopsided. This problem may be aleviated by placing the attaching decoupler at a point above the relative center of gravity, in effect, balancing the elevator for proper docking.

This system will be most useful to a VGF that incorporates the use of rotational speed to vary artificial gravity. However, a counterweight system similar to most modern chairlifts will allow the system to become wider to vary the artificial gravity.

7.7 Summary

A space elevator depicted on Figure 7.A will serve the (VGF) space station better than the other alternatives studied. The disadvantages of minimal safety and drag problems are far outweighed by the advantages of less weight, simplicity, current technology, and less maintainence that we get when using this transportation system.

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Chapter 8

FIRE

Paul Novak, Kay Pues, Charles Simons, Michael Trost, Charles Tye

.1 Definition of Topic

Controlling space habitat fires concerns six things: fire prevention, detection, evaluation, containment, clean-up, and damage repair. All of these must be done in a safe, economical way that saves lives, money, and resources.

.2 Questions

Some questions must be answered to do an adequate job in preventing, detecting, evaluating, containing fires.

1. What kind of alarms will be needed? Audio, visual, computer monitored, or manually activated? Singly or in combination?
2. How much fire prevention, detection, and evaluation equipment is practical?
3. Where will alarms be placed? How many alarms, total and by type, are needed?
4. What kind of extinguishers or firefighting techniques should be used? Should the equipment be located in single or multiple locations?
5. What materials should be used?
6. How fire proof, retardant, or resistant should materials be? Whose standards should be used?
7. How should cleanup and repair be attempted?
8. What should the people do and where should they go during a fire?
9. Should computers be used? For what operations?
10. What type of fires can happen in a space habitat?

.6 Design Requirements

The vgf must be built with proper consideration for preventing, detecting, evaluating, and containing fires. It must also encompass clean-up, damage repair, and detox (cleaning the air of toxic and combustible gases) procedures after the fire is extinguished. All this must be done with concern for the crew's safety and well-being before, during, and after the fire.

.7 Expanded Design Requirements

Four steps will prevent a fire or stop its spread.

1. Fire Prevention
   All materials should, if possible, be made of non-flammable substances such as Norfab, Neoprene, glass fiber, and graphite. Materials should be capable of withstanding flame tests as specified under FAA regulations (8001, parts 25, 29, and 121). If flammable material is unavoidable it should be self-extinguishable and not give off toxic or combustible gases since such gases are the largest killer in airline fires (8002, p. 41).
2. Fire Detection
   Alarms should provide accurate and adequate forewarning of a fire. This includes heat and smoke alarms (8003, pp. 44-45). All heat and smoke alarms should be computer monitored with manual override capability in case of false alarms. Alarms can announce a fire's existence in one, or a combination, of the following ways:

1) A computer synthesized voice warning of a fire's existence.
2) Audio tones that vary by pitch, time interval, and\or length of time the tone is heard. The tone could correspond to the fires's location and extent. Placards would be posted listing the coded information.
3) Lighted boards showing the fire's location and extent.

Heat and smoke detectors would be located in all inhabited areas, areas containing concentrated electrical or computer equipment, ventilation ducts, fuel storage, and lab areas.

3. Fire Evaluation and Containment
Next is deciding how to handle a fire in the safest and most efficient way possible. This can be done in one, or a combination, of the ways listed below:
    1) Decision by trained personnel
    2) Decision by computer monitoring system
4. Cleanup, Damage Repair, and Detoxification (Detox)

NOTE: Some fire protection and rescue planning procedures used for the space shuttle and space station could be studied and employed (8013, pp. 34-40, 127-128).

.4 Unanswered Questions

One vitally important question must be answered: How do fires burn and spread in zero-g or fractions of a g? At what minimum g level does convection begin working?

Without this information all the above precautions could be useless or even dangerous when dealing with an actual fire. In addition, decisions on how to fight the fire could be made on false, possibly dangerous, assumptions.

.5 Obtaining Data and Information

The only way this information can be obtained is through actual experimentation in a zero-g or variable-g environment. A possible alternative is to talk with firefighting experts or consultants to gain an understanding of techniques used to prevent, detect, and fight one-g fires.

.8 Solutions

1. Fire Prevention
Allow no uncontrolled or unmonitored burning. Make everything as flame retardant as possible.
2. Fire Detection
Use heat and smoke alarms and place them in the places previously mentioned (.3). Use computers to locate the fire.
3. Fire Evaluation
Computers should be used to help evaluate the fire's severity. Oxygen masks should be provided for the crew only after the fire is extinguished to avoid "fanning" the flames or killing the crew due to oxygen starvation or polluted air. "Safe rooms" (a place where a person has a livable atmosphere) should be provided for the crew

in hazardous areas. Shut down the circulation system (fans) to cut off the fire's oxygen supply and allow it to "drown" in its own gas byproducts. Use portable halon fire extinguishers (8012, pp. 18-21) or flood the entire compartment with firefighting foam or inert gases from fixed, wall-mounted extinguishers (8004, pp. 76-78). As a last resort, put the fire out by exposing the cabin to vacuum which vents the fire's air supply.

4. Detoxification
Expose the cabin to vacuum in order to cleanse hopelessly polluted atmosphere of toxic or combustible gases.

.9 Viability of Solutions
The fixed inert gas fire extinguishers have a failure rate of 23% (8004, p. 78). The cost and weight of these installations would be proportional to the station's size, but a halon 1301 portable container by Metalcraft is 15 ounces lighter than its competitor (8012, p. 20). Halon 1301 is considerably less toxic than other halon types and has disadvantages in only two areas: a less controllable distance and that it's under 360 psi which is considerably more than the Halon 1211 extinguishers (8012, p. 19).

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Chapter 9

Facility Designs

By: Randel B. Hagen

Variable Gravity Research Facility

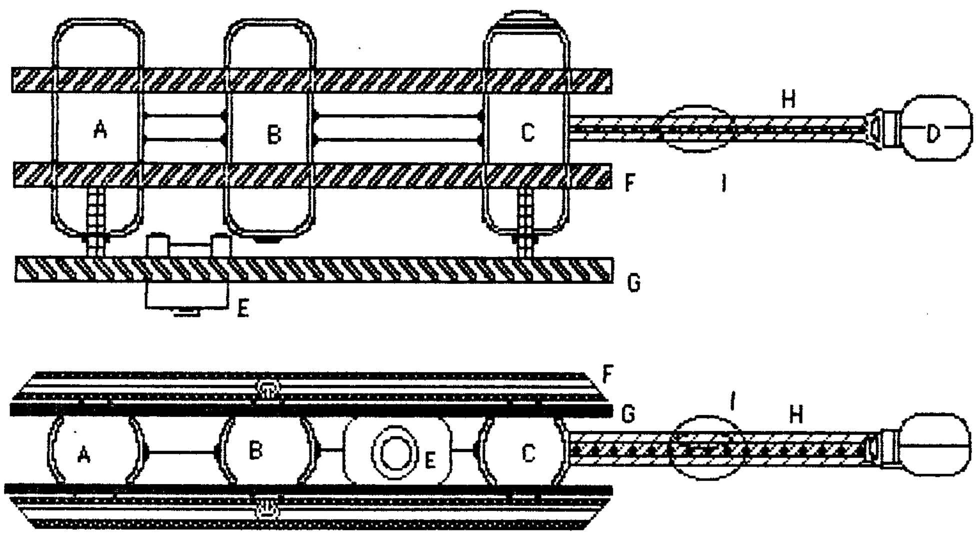
Definition of Topic

This paper will show several different design ideas for the Variable Gravity Reasearch Facility. All equipment in these designs use over the counter equipment.

Variable Gravity Research Facility

Limited Tether System

This system uses a rigid structure to maintain its integrity. The cross beams are made of a highstrength plastic that is wrapped with Kevlar to protect it from solar radiation.



Modular Componets

A) Section A is a 1g. research station. It could contain equipment and computer space needed for research of earths atmosphere. Sleeping quarters for up to five crewmen could be avaible in earth like gravity.

This section of the station would be the size of the shuttle bay and may be made in the same basic design as that of the space station.

B) Section B is a variable gravity module. Crewmen that are undergoing the gravity test will stay in this facility. It may also contain small experiment stations that are interchangable with each other.

This section will be moved between the 1g. and 0g. facilitys by tethers the are connected to winches in the 0g. facility. High strength plastic support beams will hold large rollers that will slide through.

Again this section will be scaled to the size of that of the space station units. This section will be self contained, but may share power and air with the other facilities through ductwork in the cross beams. But the section must be self contained in a matter of seconds in emergancy situations.

C) Section C is the 0g docking module and equipment/supply storage section. This section will contain the main power winches which are need to move the variable gravity section into place.

The space shuttle will dock with this section most of the time because this is were the supplies are to be kept. The radio antenna will be located on this section due to the fact that it move very little and less repositioning will be nessary.

This section like the other two will be self-contained so that it will be possible for some one to live there for a short period of time if the emergance called for it. The fuel cell will be contained in this section and will be resupplied from the shuttle when nessary. This station should not need a large amount of space for fuel storage because spin up will be done with the space shuttle conected and using the shuttle main engines for boost. The only time the stations engines will be used is for oribtal maintance.

D) Section D is the main power sourse for the facility. The power for the station will come from a nuclear power sourse. The power module will be kept at the greatest distance possible. This module will have an emergancy release system incase of problems so the contamination will not effect the station. The module will be equiped with a self destruct system that will keep the power sourse from contaminating other things or form intering earths atmosphere.

E) Section E is the elevator for the station. This elevator will be capable of moving between the sections and docking with them. There will be three docking bays in the elevator, two facing the station and a main one the is facing towards the outside. The main docking bay will be use by the shuttle to transfere material to the station.

The elevator will be selfcontained for up to 72 hours in case of problems crew member will not be lost. The elevator will move with the assistance of cabbles and winches that are located on the ends of the support beams. The elevator moves toward the station by the use of hydrolic fluid in the cross supprots that are located on the 1g and 0g facilites.

F) Section F is the main support beams. These four beam are made of a high strength plastic that has holes for the movement of the variable gravity section.

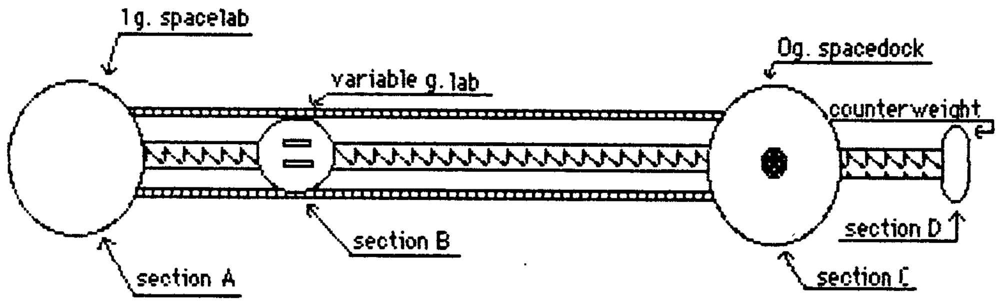
The beams will also contain the power cables and main station air suppy lines. These beams will be conected together with large cotter pin connections. This will cut down on outside construction times. These beams may be brought up by the shuttle or by disposable rocket.

G) Section G is the support beams for the elevator. These beam will be connected the same way as the main support beams. There will be two winches that will be used to move the elevator back and fourth.

H) Section H is the main support for the power sourse and dead weight sections. This support will be connected like the rest only it will be larger. The section will contain a winch that will move the dead weight section. There will also be explosive end caps on the end containing the power sourse.

I) Section I is the dead weight section. This weight is use to counter the movement of the elevator and variable gravity sections. This section will be made up of junk or a external tank.

Variable Gravity Research Station



Section A: 1g. Research facility

a) This facility may station doctors and researchers in an earth normal gravity for extend periods of time.

b) Facility may be launched prefabricated from earth as Skylab was.

c) Facility would have two air locks one for personal EVA and the other for shuttle docking.

d) This section may contain the propulsion system for the stations rotation.

e) Facility would be self-sufficient for up to 60 days incase of accident or system failure.

f) Facility may range in size from shuttle bay size to that of skylab.

Section B: Varirable g. Habitat

a) Shuttle bay sized personal habitat, that would serve as living quarters for test subjects.

b) Contains two air-locks for access to 1g. and 0g. facilities.

c) The subjects will preform a number of experiments along with caring for lab animals.

d) The size of crew can range from 3 to 5 members.

e) Exercise equipment will be located along with a number of test equipment.

f) The Habitat will move along rollers and be controled by computer.

Section C: 0g. Spacedock

a) Dock will contain tractor motors maintenance equipment.

b) Bulk supplies and main shuttle lock will be contained in this section.

c) This section will be roughly the same size as the Research facility, and will be launched in same manner.

d) Control mechanism for counterweight will be located here.

Section D: Counterweight

a) This section may very in size and shape.

b) Nuclear power plant may be located here to provide power.

c) This section is open to design options.

Conclusion

These two designs are both easily placed into space using the space shuttle and rockets such as the atlas or titan. The first design is the most reliable of the two because of the better design of the elevator system.

These two systems use a more ridged system of support the will better hold up under the stress of space conditions. With the different gravities that take place on the same structure the more wide range the number of experiments that are avaiable to work on. This entire system could be an extension of the space station with shared access.

The cost of the system will be kept down do to the fact there is little if any raw designs needed to be developed. All modules are of the same size and type as that of the space station. Also due to the large number of experiments that can be accomplished there will be a chance of charging companys money for lab work done with this facility.

The data that this facility will be able to gather will greatly advance the knowlage of what the gravity needs are for a person to keep healthy and in to shape.

Chapter 10: Docking 1

Dave Hoffmeister
April 29, 1987

10.1 Definition of Topic

Docking is the mechanical joining of the space shuttle and Variable Gravity Facility (VGF) while in space, using reaction control thrusters to maneuver the shuttle into contact with the VGF (10007, p. C25).

10.2 Background Information

The VGF docking port(s) will be despun for docking; failure of the port spin sensors in a docking port can be acceptably guarded against, at minimal weight and power penalties, by using redundant sensors: gyroscopic sensors are available weighing 81 grams and consuming 600 mW of power (10002); piezoelectric sensors are available with even greater weight savings, due to their lack of motors, magnets, and other moving parts, and consuming less than 125 mW of power. The latter are said to have an MTBF in excess of 10,000 hours (10003, p. 47). Laser gyros should also be considered, but they would have to be installed/

shielded in such a manner that their dither (vibrations and related noise) would not effect shuttle or VGF equipment (10014, p. 409).

The VGF will rotate throughout the docking procedure; i.e., the VGF itself will not be despun for docking.

VGF docking port(s) must be compatible with shuttle port used for docking with the space station.

The VGF is assumed to be in a known, stable, rendezvous-compatible orbit (approximately the same as that of the space station--altitude 250-270 NM) (10014, p. 126); rendezvous-compatible orbits are those orbits, having unique combinations of altitude and inclination, which ensure that the VGF would be at the proper aim point as its orbit plane passed through the shuttle launch site. Putting the VGF in such an orbit will place it over the launch site at regular daily intervals, and if its orbit is inclined beyond the launch site latitude, such positioning could occur twice per day (10019, p. 383). This would allow two launch opportunities per day, reducing the chance of weather causing repeated cancellations of a vital launch (VGF emergency, etc.), and would reduce expensive and complicated detanking of launch vehicle cryogens and other cancellation requirements (10019, p. 384). Another advantage of rendezvous-compatible orbits is minimized shuttle flight time for rendezvous with the VGF (10019, p. 390).

The VGF crew will not be able to directly control the shuttle's approach, partly because it would require that all of the associated maneuvering and telemetry equipment be onboard the VGF, and partly because the procedure will require a specialist at the controls should the automatic systems fail.

No EVA will be required for docking.

The docking tunnel from shuttle to VGF will be pressurized.

The VGF will be spinning about an axis of the central cylinder, but will not be tumbling about any other axis.

Rendezvous Phase 1 means the time from launch until the shuttle crew has the ability to track the VGF electronically or visually.

Rendezvous Phase 2 means the time from the end of Rendezvous Phase 1 until the shuttle is in a pre-specified offset position behind the VGF (relative to VGF orbital path)--the so-called "Stable Orbit Rendezvous Technique" (10014, p. 358). This will place the shuttle approximately 1000 feet from the VGF (10014, p. 359).

Approach Phase means the time from the end of Rendezvous Phase 2 until the beginning of shuttle orientation for docking (alignment along the proper axis for final approach to VGF docking port) (10014, p. 369).

Docking Phase means the time from the end of the Approach Phase until the shuttle and VGF are coupled together.

Separation Phase means the time from initial actions to disconnect VGF and shuttle docking ports (sealing airlocks, releasing capture latches, etc.) until shuttle is beyond its expected explosion range from the VGF (to reduce chance of VGF damage during an explosion occurring at time of shuttle orbital transfer maneuver ignition (10014, p. 369).

Proximity Operations refers to any operations which take place while the shuttle and VGF are within one mile of one other, and would thus include approaches, docking, separations, and flyarounds ("missed approaches," and inspections of the VGF carried out by the shuttle).

Continuous radio contact will exist between shuttle and ground control personnel during Rendezvous Phase 1, and between shuttle and VGF personnel during Rendezvous Phase 2, Approach Phase, Docking Phase, Separation Phase, and proximity operations.

10.3 Proposed Mission Requirements

Ground control must provide tracking and vectoring support for Rendezvous Phase 1, if the computerized rendezvous track turns out to be inadequate after launch.

Shuttle crew must be able to complete Rendezvous Phase 2, Approach Phase, and Docking Phase without assistance from Ground Control or VGF crew, and should have the capability for total active control of rendezvous, approach, docking, and separation phases (10014, p. 551). However, shuttle Guidance, Navigation, and Control (GN&C) computers should be capable of responding to ground signals, as an emergency backup (during crew incapacitation, etc.) (10014, p. 731). GN&C system will provide onboard calibration and alignment of sensors, control of RCS (Reaction Control System) thrusters, and safety checks and shuttle control during proximity operations. Shuttle instrumentation will thus have to provide range, closure rate, and angular information. At least four types of sensors are capable of doing this: rendezvous radar, in the 2-30 cm wavelength range; ladar (laser detection and ranging), in the 0.8-11 um range; LWIR (Long Wavelength Infrared), detecting thermal VGF emissions from 6-16 um; and passive sensors, utilizing solar radiation reflected from the VGF in the visible range from 0.4 to 0.8 um (10020, p. 4). The latter two, it should be noted, would restrict docking with the VGF to "daylight" hours (when the VGF is not in the earth's shadow).

Shuttle and VGF must both have some means of positively confirming the quality of dock connection (all required connections satisfactorily mated).

Docking ports for space station, VGF, and shuttle will all be androgynous (10009, p. 183).

It is vital that the shuttle and VGF remain aligned along pitch, yaw, and roll axes while docked, due to damage to the docking ports which could result from flexing, and from the catastrophic impact which would result if the shuttle were to contact the VGF's rotating tethers. After docking, the structural rigidity of the docking mechanisms will be responsible for keeping the two spacecraft aligned along pitch, yaw, and roll axes; no RCS thruster firing will be allowed while docked (10009, p. 156). This is important because of the damage and contamination of the VGF/tethers which may result from RCS exhaust gasses (the "plume" shown in fig. 1). Firing of the thrusters while near the VGF (i.e., during approach, docking, and separation) should thus be kept to the absolute minimum necessary to perform any given maneuver (10014, p. 565). In addition, firing of the thrusters while docked would exert a force ("over-pressure") on the VGF (fig. 1), possibly affecting its stability (by causing tether flexing), its plane of rotation, and in a drastic case even its orbital position (10014, p. 368). It is worth noting that EVA should probably be restricted during docking and departure, due to like effects of the plume on astronauts (10014, p. 740). Conservation of thruster propellant is also a desirable aspect (10014, p. 368).

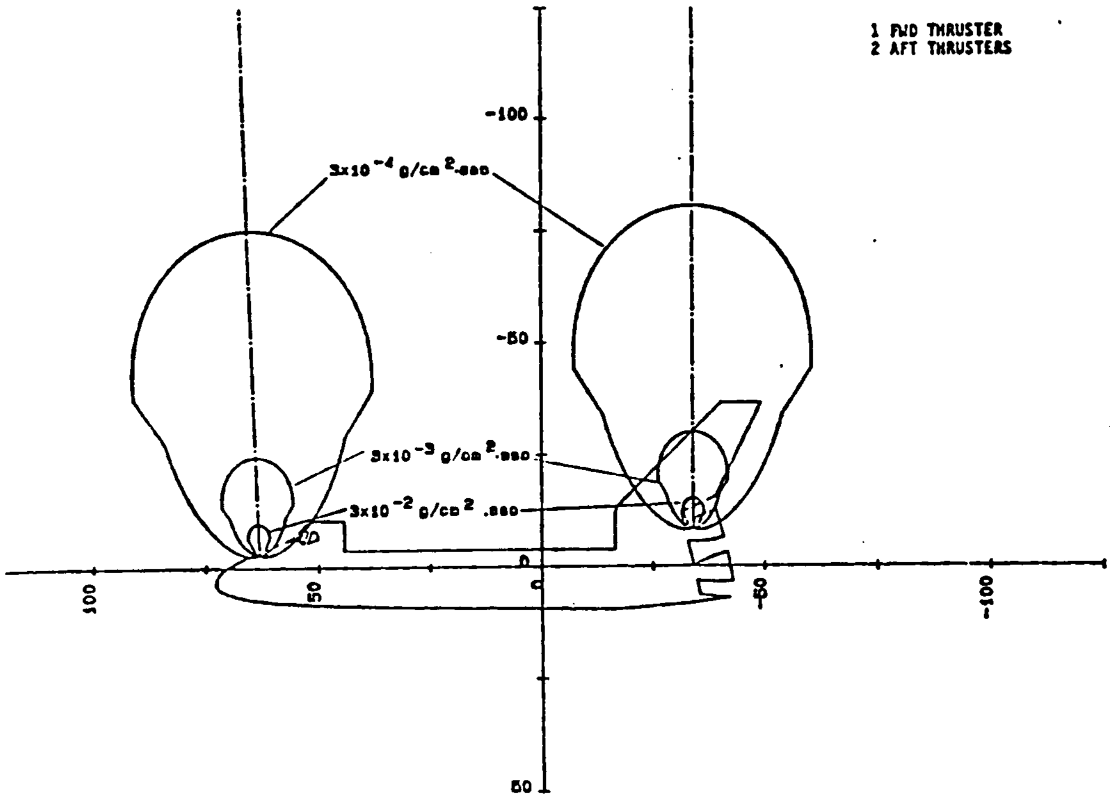


Figure 1 - ORBITER THRUSTER PLUME CONTOURS

Safety mechanisms should exist to minimize damage caused by explosive decompression of airlocks or docking tunnel, and to relieve possible overpressurization of airlocks or tunnel. These will be more critical on the VGF than on the space station, due to the weak link presented by the despinning joint.

Docking port position must provide the shuttle with adequate clearance from VGF tethers, both when docked and while maneuvering before/after docking.

Some means should exist for determining whether excessive side loads (i.e., forces other than along the lengthwise axis of the docking port) are being applied during docking, while docked, or during separation. This is especially important for the VGF, as structural failure of the docking port could result in the shuttle contacting the VGF tethers.

Some fluids or other substances that flow through connections between the shuttle and VGF docking ports (fuels, hydraulic and thermal control fluids, etc.) may be capable of damaging the port (10014, p. 564). Were some substance to leak from its line and corrode/oxidize part of the port latching mechanism, a potentially lethal situation could arise on a VGF with only one docking port (the shuttle would effectively be frozen/welded to the VGF's only airlock . . .). Lines carrying such substances should be judiciously segregated, appropriately encased, and automatically monitored.

10.4 Proposed Method of Meeting Mission Requirements

Central Cylinder Perpendicular to Outer Cylinders ("T" arrangement--fig. 2).

Shuttle will rely on computerized launch path control and ground control tracking during Rendezvous Phase 1.

Rendezvous Phase 2 will make use of Doppler Velocity Sensors (DVS), transponder (on VGF: Ku-band radar, to augment Orbiter Rendezvous Radar tracking), and ladar equipment, supplemented by visual markers on the VGF (10014, p. 437). Use of ladar will require that the skin of the VGF near the docking port be "surface conditioned," to avoid any problems with spurious specular reflections from surfaces adjacent to the ladar reflectors placed around the port (10020, p. 9). Visual markers may take the form of flashing lights; however, lights should only be lit on rotating (relative to the shuttle) portions of the VGF when vital for confirming distance between shuttle and VGF/tethers, due to the possibility of their rotation inducing vertigo in the astronaut performing the docking procedure (10004, p. 9). It would also be wise to ensure that more than one light can be seen by this astronaut at any given time, to reduce the possibility of autokinesis (10011, p. 69). Keeping the docking port well lit during docking would alleviate this, in addition to facilitating visual maneuvering.

The approach and docking phases will use DVS and ladar measuring equipment for final maneuvering, in addition to visual cues seen through the shuttle bay windows and relayed from appropriately

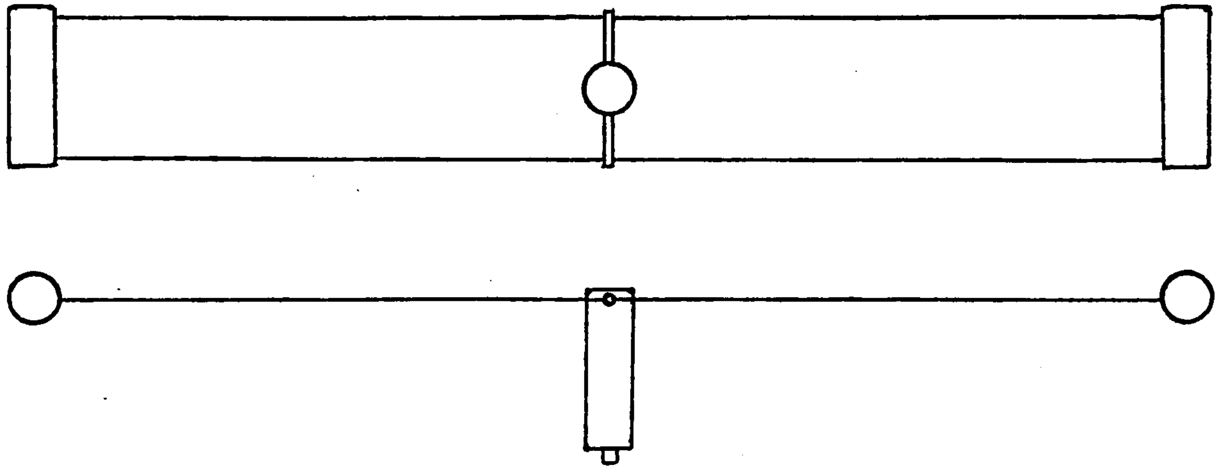


Figure 2

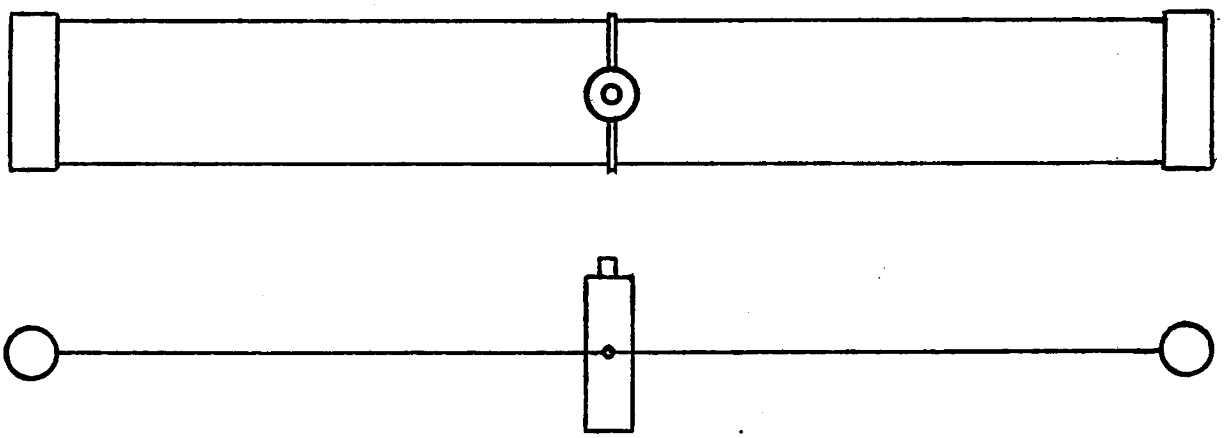


Figure 3

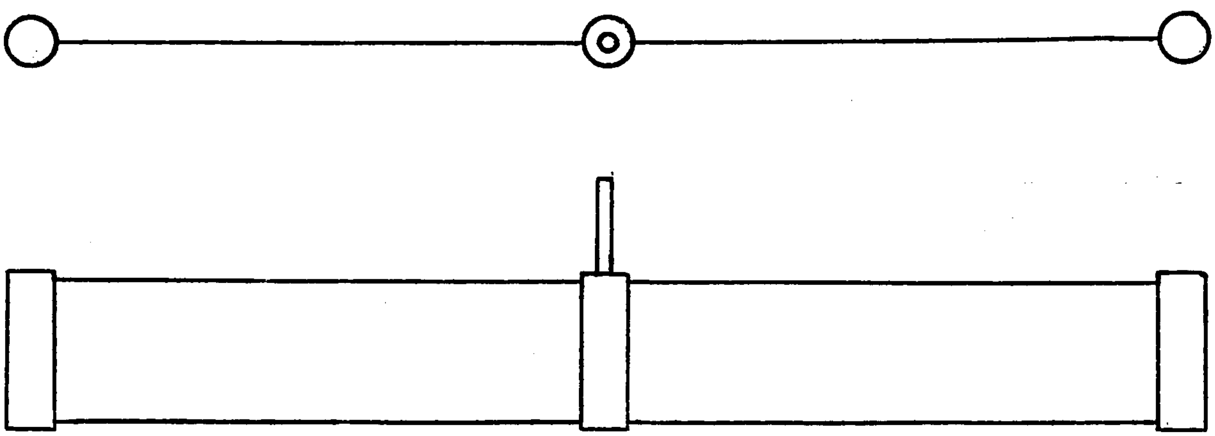


Figure 4

placed TV cameras (10017, p. 1031). Ladar system will provide information on target range, rate of closure, angular position, and attitude relative to VGF (10014, p. 437). Attitude can be determined by measuring the relative position of several laser reflectors installed in a known arrangement on the VGF (around the docking port); to keep docking procedures similar, this arrangement should be the same on all spacecraft with which the shuttle will dock. Measuring range and closure rate of individual reflectors requires that the tracking sensor have a high range accuracy, wide field of view, narrow beamwidth, and a fast random-scan capability. This suggests that the best sensor would be a continuous wave optical radar (semiconductor laser transmitter and image-dissector receiver) (10018, p. 2.2.2). This selection is laudable due to its precision, small size, and security (relatively unaffected by outside sources of interference). In addition, this sensor information would allow automatic stationkeeping, relieving the crew of the tedium and workload of monitoring sensors/executing corrective maneuvers (10018, p. 2.2.3). Computers will check ladar measurements against DVS measurements, to ensure that the data used to control the thrusters is not faulty. If both ladar and DVS systems were to fail, or capacity for autocoupling were lost, crew would rely on COAS (Crew Optical Alignment Sight) and rendezvous radar data during docking (10014, p. 368).

Rendezvous Phase 2 will begin when the shuttle crew activates tracking sensors, differentiates the target from clutter if necessary, and initiates the autotrack mode; initial range measurement should occur beyond 250 NM from the VGF, to allow sufficient time for updating navigation computations (10020, p. 3). The crew will monitor sensor output and spacecraft status on the VDTs, and compensate (adjust system) for any enviromental or sensor anomalies. This will continue through the approach and docking phases, or crewmembers may choose to manually dock the spacecraft (10007, p. 56). The Approach Phase will be complete when the shuttle is oriented so that it can approach directly along the central axis of the docking port. Approximately 800 feet from the VGF (near the end of the Approach Phase), two initial burns will occur, placing the shuttle on a closing trajectory with the VGF. At approximately 575 feet, a series of braking maneuvers will be initiated to reduce the approach velocity; all rates should be nulled at approximately 50 feet (10014, p. 371). Docking will be complete when the docking latch solenoids are activated by proximity switches in the corresponding port, causing capture latches to engage; dock is not considered complete if readings indicate that any connection (electrical, hydraulic, pressurization, etc) is not adequate (10007, p. 326).

Separation Phase will consist of disconnecting the shuttle and VGF from one another, initiating an approximately 0.2 fps separation rate directly away from the VGF docking port, coasting the shuttle away from the VGF for approximately 15 seconds, and then accelerating to a larger separation rate of approximately 3.0 fps. This will be maintained until the shuttle is beyond its assumed explosion range from the VGF (approximately 10 NM);

Separation Phase will be complete when shuttle has reached this distance. Ladar and DVS will be used throughout the maneuver.

Docking port will use electromechanical devices (like MMU trunnion pin attatchment devices) to pull ports together once they are aligned (10005, p. 25; 10009, p. 156). Capture latches will also be designed to allow manual operation (ex.--by hand crank), if latch drive fails (10007, p. 327).

Data from DVS, transponder, and ladar sensors will be fed to computer for firing of orbiter RCS. Primary maneuvering engines (870 lbs. thrust) will be used in rendezvous phases; vernier maneuvering engines (24 lbs. thrust) will be used for final part of Rendezvous Phase 2 and during Approach, Docking, and Separation Phases (10001, p. 1.29).

Distance and velocity information from sensors will be used to alert the maneuvering astronaut(s) if closure rate is too rapid, or if a collision will result if appropriate thrusters are not fired immediately. A simple and easily/rapidly assimilable display of this information, in addition to digital readouts, would be a three-light group with green, yellow, and red colorings corresponding to normal, warning, and hazardous conditions; in addition, an alarm should be tied to the latter two. On an auto-coupled approach, the system would fire appropriate thrusters automatically if a warning or hazardous condition developed.

Docking port sensors will relay information concerning the quality of dock connection (pressurization level, rate of pressure change, hydraulic and thermal control fluid, electrical, and optical connections, and locking of all capture latches) to shuttle and VGF consoles. Alarms should sound at both consoles if any vital parameter changes while spacecraft are docked.

Warming systems should be installed in the docking ports, to ensure hermetic coupling of any fuel/hydraulic lines (10012, p. I-184).

Monitoring of conduit carrying fluids or other substances between the shuttle and VGF will be done with temperature, fluid and vapor pressure, and flow rate sensors; occurence of abnormal readings will trigger appropriate alarms aboard both the shuttle and VGF.

Pressure sensors and sensitive accelerometers will be placed in the docking ports, to warn the crew when unsafe loads are being applied. This includes side loads, and forces acting along the central cylinder's lengthwise axis (which could adversely affect VGF position and stability).

Docking mechanism should contain shock absorbing devices, to reduce chance of damage to itself, shuttle, VGF, or despin joint seals resulting from improper speeds/maneuvering while docking (10009, p. 156).

Docking ports will have pressure equalization valves, for equalizing shuttle airlock, transfer tunnel and VGF airlock pressure (10008, p. 3-27).

The transfer tunnel/airlock combinations will have self-closing airlock doors, which can be armed from shuttle and VGF consoles after docking. When armed, doors will close automatically if shuttle or VGF airlock, or transfer tunnel, undergoes explosive decompression.

McDonnell Douglas suggests that the following criteria for manual docking not be exceeded:

Axial closing velocity	:	0.16-0.50 ft/sec
Lateral velocity	:	0.25 ft/sec
Angular velocity	:	0.6 deg/sec
Pitch, yaw, and roll misalignment	:	+/- 5.0 deg roll +/- 6.0 deg pitch and yaw
Radial miss distance	:	1.0 ft
Lateral misalignment	:	0.75 ft (10007, p. c25)

The above criteria can be measured by currently available sensors, to a degree of accuracy greater than that required:

max range of docking sensors	:	1000 ft
coverage	:	20 deg cone
accuracies--range	:	+/- 0.02 ft
--angle	:	+/- 0.1 deg
--velocity	:	0.03 ft/sec
--attitude	:	+/- 0.57 deg (10014, p. 427)

When and where in orbit the meeting between shuttle and VGF can occur will depend to a significant extent on lighting, due to the shuttle crew's need for adequate visual contact with the VGF. This includes both sufficient light to see the VGF, and a sufficiently great (more than 20 degrees) angle between shuttle-VGF line of sight and shuttle-sun line of sight (i.e., the crew should not be expected to look directly into the sun while maneuvering) (10014, p. 385). Additionally, placement of any high-intensity lighting on the VGF, installed for the purpose of illuminating the docking area, should also be adjusted (angle and intensity) so that it will not blind the astronaut(s) maneuvering the shuttle. This discussion suggests that the best possible maneuvering environment would be one with the sun behind the shuttle, taking place as soon after orbital sunrise as possible (10014, p. 369). Due to the relatively slow rotational speed of the VGF, it seems unlikely that flicker vertigo (induced by tethers passing in front of the sun, or if they are shiny, reflecting its rays) could occur (10015, p. 1).

Like the space station, the VGF might benefit from having certain types of "controlled space" around it. This is partly due to the resulting standardization of flight planning and operations, and crew planning and operations. Zones could also support collision avoidance (with more than one shuttle near the VGF), and help reduce contamination and disturbance of the VGF resulting from RCS firings (10014, p. 356). The following zones are numbered from "inside-out" (i.e., the zone closest to the VGF is number one).

Zone 1: Proximity Operations Zone

The space inside a one mile in diameter sphere, centered on the VGF. All proximity operations, plus EVA/MMU operations, will occur within this zone (10014, p. 357).

Zone 2: Rendezvous Zone

Cylindrical shell centered on the VGF, having a 10 NM radius and a length of 200 NM (100 NM in front of and behind VGF) along its orbital path. All rendezvous with the VGF will be targeted to place the shuttle in Zone 2.

Zone 3: Buffer Zone

Cylindrical shell having the same orbital path dimensions as Zone 2, and extending outward five NM from the edge of Zone 2 (15 NM radius from VGF). For the purpose of separating any parked craft from craft rendezvousing with the VGF.

Zone 4: Parking Orbit Zone

Cylindrical shell having the same orbital path dimensions as Zones 2 and 3, and extending outward 20 NM from the edge of Zone 3 (35 NM radius from the VGF). For use by craft needing to stay "on station" near the VGF (while waiting for a free docking port, for a hazardous condition on the VGF to be contained, etc.).

10.4.1 Discussion of Proposed Method

advantages:

Provides greatest distance between shuttle and VGF tethers, due to placement of docking port at far end of center cylinder from tethers (fig. ~~3~~ 2).

Relatively stable, because forces on the outer cylinders would tend to keep them in their intended plane of rotation.

Variety of tracking sensors and computer crosschecks between sensor types increases the accuracy of tracking information.

Manual and automated rendezvous/docking allows backup for equipment failures, and crew incapacitation in an extreme situation.

Less volume to pressurize during docking/EVA than designs utilizing docking port extensions.

disadvantages:

No backup if the only docking port fails/is damaged.

Requires tether attatchment rods, increasing weight and cost.

Tether rods could be a structural weak point, depending on their size, method of anchoring, and the magnitude of loads imposed upon them.

Slightly greater g forces at one end of outer cylinders, due to lengthwise axis of outer cylinders being parallel to spin plane (rotation is around lengthwise axis of central cylinder).

Provides less distance between shuttle and tethers than proposed method (10.4).

10.4.2 Weight Estimates of Proposed Method

On VGF:

Transponder transceiver	:	2.7 lbs.	
Antenna	:	0.2 lbs.	(10013, p. 6-28)
Gyro despin sensor	:	2.88 ozs.	(10002)

On Shuttle:

Guidance and Control processor	:	20 lbs.	
RCS control system	:	35 lbs.	(10014, p. 419)

Could not find any information on weight of docking modules, quality-of-dock sensors, DVS, ladar system, or transponder receiver.

10.5 Alternate Methods

10.5.1 Central Cylinder Perpendicular to Outer Cylinders ("+" Arrangement)

advantages:

Provides safe clearance between shuttle and VGF tethers, without using port extensions or reducing VGF stability by moving tethers inward (fig. 3).

Relatively stable, because forces on the outer cylinders would tend to keep them in their intended plane of rotation.

Less volume to pressurize during docking/EVA than designs utilizing docking port extensions.

disadvantages:

Requires tether attatchment rods, increasing weight and cost.

Tether rods could be a structural weak point.

Slightly greater g forces at one end of outer cylinders, due to lengthwise axis of outer cylinders being parallel to spin plane (rotation is around lengthwise axis of central cylinder).

No backup if the only docking port fails/is damaged.

10.5.2 Parallel VGF Cylinders, Single Docking Port and Extension

VGF docking port will be at the end of an airlock extension attatched to the center cylinder (fig. 4), to ensure adequate clearance between the shuttle's vertical fin and the VGF tethers; the extension will need to be greater than 25 feet long, if tethers are placed at the ends of the VGF cylinders, due to the height of the shuttle's vertical fin (10001, p. 1.2--1.3). This extension will be permanently attatched to the VGF's despun port (requiring that the despinning mechanism be structurally capable of supporting the extension's mass, and powerful enough to despin it). The extension will contain the wiring, optical fibers, tubing, etc. which will provide connections between the VGF and shuttle while the two are docked, in addition to providing an environmentally safe access tunnel for astronauts/supply transfer between the spacecraft. The extension will also be usable for EVA exit/entry.

Docking port extension will only be pressurized when the port is being used, to reduce any leakage of the VGF's atmosphere through the despinning seals (between VGF cylinder and extension).

advantages:
Relatively stable, due to placement of the tethers at the extreme ends of the cylinders (fig. 2). As tether attatchment points are moved inward, tendency of the outer cylinders to remain parallel to the center cylinder decreases, with possible resultant oscillations and loss of stability.

disadvantages:
The port extension represents an extra volume to pressurize during docking/EVA.

Forces applied at the end of the extension's long arm could cause damaging loads at its base (where extension is joined to VGF cylinder). External braces between the end of the VGF cylinder and the sides of the extension could be added, but this would require that the entire end of the VGF be despun for docking (as opposed to only despinning the port and extension). The extension could also be extended a short distance into the VGF, for structural support.

Forces applied at the end of the extension's long arm could also affect the VGF's spin attitude/stability.

Any divergence of the port extension's lengthwise axis from the VGF cylinder's lengthwise axis would result in the docking end of the extension moving in an exaggerated circular path, rather than simply rotating. This would obviously make docking difficult, if not impossible.

NASA has suggested that forces acting on the outer cylinders will tend to rotate them so that their lengthwise axes will be in the plane of rotation. This would twist the tethers, possibly resulting in damage and reduced stability.

No backup if the only docking port fails/is damaged.

10.5.3 Parallel VGF Cylinders, Two Docking Ports and Extensions

advantages:

Port redundancy provides backup for failed/damaged port (fig. 5).

Convenience and safety: allows docking or EVA from second port

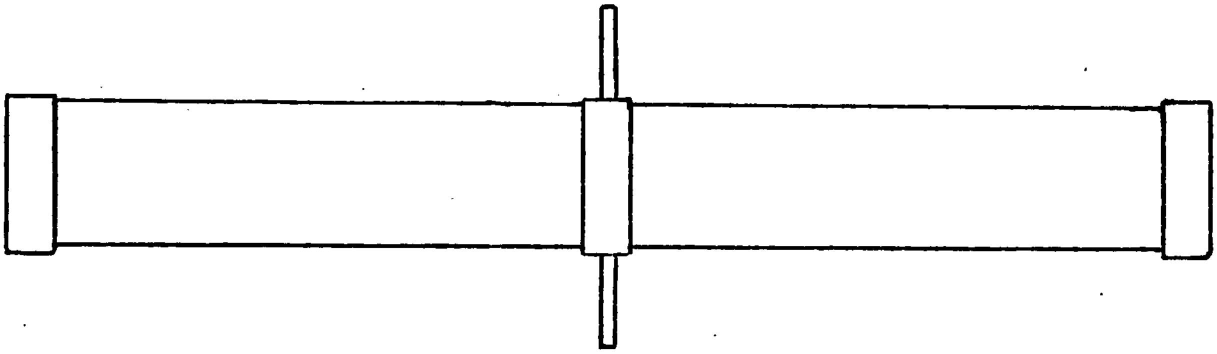


Figure 5

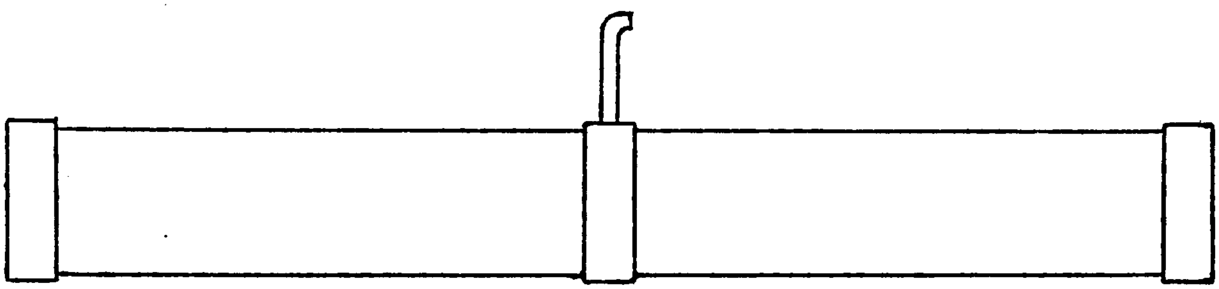


Figure 6

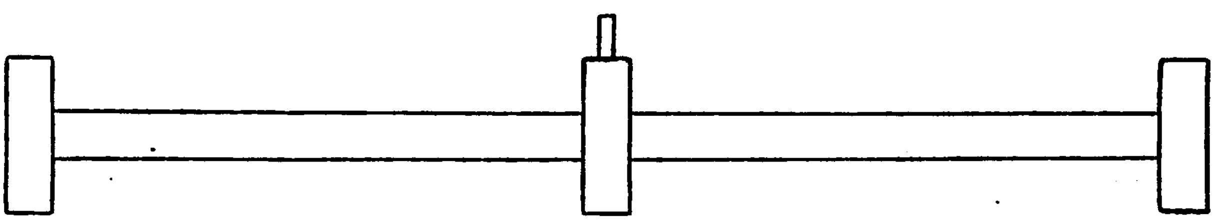


Figure 7

if first port is in use (shuttle docked).

Relatively stable, due to placement of tethers at the extreme ends of the cylinders.

disadvantages:

Long port extensions increase the chance of damage due to side loads incurred during docking.

Redundant ports are more expensive, and carry a weight penalty.

Forces on the outer cylinders may change their spin attitude, as mentioned in 10.5.2.

Port extension represents extra volume requiring pressurization during docking/EVA.

10.5.4 Parallel VGF Cylinders, Single Docking Port and Extension with Elbow

advantages:

Relatively stable, due to placement of the tethers at the extreme ends of the cylinders (fig. 6).

Keeps shuttle tail farther from tethers than other designs, except proposed method (10.4).

Possibly improved visibility for maneuvering astronaut during docking.

disadvantages:

If port despin mechanism fails, rotating elbow could damage shuttle (and VGF at impact).

No backup if the only docking port fails/is damaged.

Entails the extra weight of the port extension and elbow.

Long port extension increases the chance of damage due to sideloads incurred during docking.

Extra bend in transfer tunnel, to move supplies past.

Greater cost and weight, due to additional materials.

Requires that shuttle nose be relatively close to long portion of port extension, resulting in reduced maneuvering room. However, this still appears to be safer than having the tail close to the rotating tethers.

Forces on the outer cylinders may change their spin attitude, as mentioned in 10.5.2.

Port extension represents extra volume requiring pressurization during docking/EVA.

10.5.5 Parallel VGF Cylinders, Single Docking Port, Tethers Moved Inward for Docking Clearance

advantages:

Shorter port extension (fig. 7), reducing chance of damage or other problems due to sideloads incurred while docking (the moment resulting from use of a nominal two foot port extension would be an order of magnitude lower than the moment associated with a 25 foot extension).

Least weight, complexity, and expense, relative to other designs.

Moderate volume to pressurize during docking/EVA.

disadvantages:

Least stable, due to requirement that tethers be close to VGF's plane of rotation (to ensure safe clearance between shuttle and tethers).

Outer cylinders are more likely to yield to forces trying to twist them into the plane of rotation, because tethers are closer together.

10.5.6 Drogue Docking Mechanism

Funnel-shaped opening centered in end of one docking port, into which probe on other docking port is inserted to center the ports on one another.

advantages:

Would facilitate capturing of VGF docking port.

disadvantages:

Drogue/probe combination would have to be removable from tunnel pathway after docking, to make use of transfer tunnel (10009, p. 220).

Would reduce androgyny of spacecraft docking ports, unless either portion of mechanism (probe or funnel) could be attatched to any docking port.

Switching funnel and probe mechanisms (as above) would require EVA.

10.6 Discussion of Unresolved Issues

NASA estimates that a force of approximately 500 pounds will be applied to a station by the shuttle, during docking, for a period of approximately one second; they mention that the actual force may be an order of magnitude lower (though the force exerted when docking a craft with Skylab was an order of magnitude higher . . .) (10014, p. 127). It would be wise to investigate whether this force could cause an oscillation in the tether system, or affect the VGF's attitude or orbital path.

Would a star tracker (for measuring angular velocity) be of practical value during rendezvous phases? (10014, p. 411).

How great a force would the tether attatchment rods in 10.4 and 10.5.1 have to support, and would their structural tie to the central cylinder be adequate without external bracing?

How much damage would thruster plumes cause to the tethers, given their current design (i.e., kevlar-coated teflon) (10021, p. 6)?

It is unclear whether not having the mass of the center cylinder evenly distributed on either side of the plane of rotation will affect stability (i.e., 10.5.1 as opposed to 10.4).

Will heat, exhaust contamination/pitting, etc. from maneuvering thruster plumes damage or reduce the effectiveness of the VGF-mounted laser reflectors? How long will it take for the plume and space dust to deteriorate the VGF skin's surface conditioning, to the point that specular reflections negatively affect the accuracy of ladar measurements?

What would the effect on the shuttle and VGF be if one of the shuttle's maneuvering thrusters were to fail "on" (10016, p. 31)?

How much pressure (PSID) will the despin joint's seal have to withstand?

What PSI will the VGF be pressurized to?

What effect will coriolis force have on docking?

Consider the number of backup (identical) systems for GN&C, sensors, etc., and resulting total weights. What systems should have backups?

The weight of laser (fibre optic) gyros could be researched (10014, p. 409).

Try to obtain specifications of COAS (Crew Optical Alignment Sight).

Try to obtain: Steering law for parallel mounted double gimballed CMGs (Control Moment Gyros)--revis. A, by Kennel. NASA

TM-82390 (10014, p. 411).

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10.7 Summary

If the forces that NASA suggests will be acting on the outer cylinders turn out to be of such magnitude as to considerably change the spin attitude of those cylinders, all but two of the designs in this chapter will be unusable. However, the two remaining designs (10.4, 10.5.1) have their own problems, in the form of structural considerations relating to the tether attatchment rods. How stable tether-linked platforms such as these would actually be, and how drastically their stability would be affected by changes in tether position, differences in weight between the outer cylinders, and forces applied by the shuttle during docking, are also unknowns. Whether the shuttle could be safely docked with a station rotating in this manner (given time lag between control movement and shuttle response to thrusters) is another question. It would seem that computer simulation (during the design process) and eventual automation of the procedure would make any hazards negligible; in addition, the relatively slow speed of rotation would reduce the speed at which relative movements between the shuttle and VGF would need to be countered.

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10-31

Chap. 11 Docking 2

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Luc R. Butzon

April 1987

11.1 Definition of topic

Docking is when one vessel joins with another and has ended when the last dynamic response, due to reactive forces encountered envolved in the docking process has stopped. (11003, p. 81)

11.2 Background information

The variable gravity facility creates a problem for the docking process, because it rotates; however, if the center is despun it will be much easier to dock with. For this report it will be asssumed that the center hub will be perminently despun or at least despun for a period of time long enough for a vessel to dock with it and to exchange supplies, produce, and/or crew members.

11.3 Proposed mission requirements

1. The two vessels must be able to dock consistantly with out error, safely and efficiently. The docking adaptor should have immediate capture - hold - release capability, undisturbed self alignment and should from a secure, rigid, sealed attachment. (11004, p. 293- 294) All this should be done without creating unnecessary reactive disturbences to the V.G. facility. (11003, p.81) Precautions should also be taken to ensure the two crafts are similarly charged before they

are to dock. Discharge of less than 2 micro joule won't effect electronic circutry. (11004, p. 309)

2. The docking port must contain an airlock large enough to transfer the crew and all supplies such as food, raw materials, equipment and any other needed products be exchanged. Size largely dependent on what will be done in the VG facility.

3. Procedures should be developed to first identify out of tolerance (position, velocity, attitude and condition of soft ware) in order to identify an emergency. Second, identify stratergies to fly by, retry or abort the docking process at any given time in case of an emergency. This procedure must be done, if at all possible, in such a way that it won't disturb the stations spin or orientation. (11003, p. 22, p. 118)

11.4 Proposed method of meeting mission requirements.

1. Docking consistancy - Spaceborne laser radar could be used for guiding the vessel in for docking. It will effectively locate and provide tracking information for a vessel that wants to dock. A prototype was built in 1972, it had a range of 94 km with a range accuracy of + or - 0.02% or + or - 10 cm (Which ever is greater) and the range rate coverage is 0 - 1 km/sec with an accuracy of + or - 1.0% or + or - 0.5 cm/sec (Which ever is greater). The radar transmitter reciever is 6" x 9" x 9" and the electronics box is 9" x 9" x 9". The input power is @ 28 VDC 40 watts total

and needs no cooling at room temp. (11001, p. 291 - 297) Along with this a video camera could be used in conjuction with a random access video memory and a micro computor with the appropriate software. Power requirements 10 W imput +-15 and +- 5 VDC. The dimentions of the total unit 220 x 60 x 70 mm. Then once the vessel is in range it could use a telescoping tube mounted with elastic material to avoid any reactive forces that might be incountered. This tube could be automatically aligned with docking port by use of photocell guidence. (11003, p. 25) The telescoping tube would also allow the two spacecraft to avoid any unnecessary closeness. This tube could be combined with the probe / dogue docking adaptor which would also include shock absorbers. The predocking conditions for this technique: (11004, p. 294, p. 299)

Range: .4 +- .1m

Lateral offset: +- .4m

Attitude misalignment: +- 5 degrees

Rotational misalignment: +- .1 degree

Range rate: .05 m/s

Lateral velocity: +- .5 cm/s

Angular rate: .5 degree/s

Rotational rate: .05 degree/s

To avoid charge difference, the two crafts should be in the same area for awhile before docking so their charges equalize with in an acceptable level. Docking should also take place outside the morning quadrant of the magnetoshere - if these steps are followed no special protective steps need to be taken for charge build up. (11004, p. 307 - 309)

2. The docking port / air lock design - Should be constructed without bend or curves and at no time should the docking port go from not spinning to spinning or visa versa. Either of these conditions would create problems when trying to transfer materials.

3. Emergency procedures - The transfer tube and docking port should be able to be sealed quickly in case, for some reason the vessel must clear the area or in case of airlock failure. This should be done automatically, after a audio - visual alarm has been activated (any significant data that could influence the docking procedure would be followed by an ~~audion~~ audio - visual alarm (11003, p. 119)). This should; however, include a manual over ride system. After this process the vessel could disconect and maneuver to safety.

Ground stations should be able to monitor, help make vital decisions and intervene if nessesary. (11003, p. 117) The only time the ground station should not be able to intervene is during the actual docking because the time delay in the communications would be too great to be of any use. (11003, p. 128)

11.4.1 Discussion of proposed method

1. Docking consistancy

A. Spaceborne laser radar and camera

advantage - small, light weight, low power consumtion, accurate, already availible and camera provides a back up.

disadvantage - if you have both laser radar and camera there will be added weight.

B. Telescoping docking - airlock tube with elastic mounting

advantage - allows for vessel to keep some distance with station and still dock, also allows for some pilot error, and creates less reactive force in the docking process.

disadvantage - maybe harder to seal because of the telescoping action of the tube.

C. Probe / Drogue

advantage - soft impact, self alignment, and accuracies are somewhat forgiving.

dissadvantages - if the probe were to miss its target it could hit the cables of the VG facility; where as, if there wasn't a probe sticking out in front it might allow more room for error.

D. Electric Charge equilization

advantage - won't interfer with electronic equipment.

dissadvantage - time could be wasted waiting for the right time to dock.

2. Docking port / airlock design

A. Avoid curves and bends in the design if possible

advantages - easy transfer of materials.

disadvantages - might be difficult to incorperate a straight docking tube into the design of the spacecraft.

B. Avoid going from spinning to not spinning section

advantages - easier to transfer materials (material, people, and supplies won't tumble)

dissadvantages - would have to come up with a device to spin and despin in order to conect with elevators or the tube could break.

3. Emergency procedures

A. Sealing port and transfer tube automatically

advantages - people involved in the emergency could worry about getting to safety instead of sealiing the compartment.

disadvantages - supplies could get trapped in door and not let compartment seal.

B. Vessel maneuvering to safety

advantages - would get vessel out of danger

disadvantage - use of thrusters at close range could interfer with the stations stability or could move the station to an unwanted position.

11.4.2 Weight estimate of proposed method

A. The total weight of the spaceborne laser radar is 40 pounds and the camera with micro computor is 5.5 kg.

11.5 Alternate methods of meeting mission requirements

A. Don't have a docking port that is functional when station is rotating. Station would have all needed supplies on board before spin-up.

advantages - less mechanical devices, less weight, and less cost.

disadvantages - couldn't efficiently get sick people, replacement people, manufactured products etc... on or off of the station.

B. Despin station in order to dock

advantages - wouldn't have to have a despun center and the center of rotation wouldn't have to be as accurate.(11002, p.70)

diadvantages - would have to store alot of fuel on board in order to despin and respin entire station.

11.7 summery

Docking should be possible at any time if only for emergency puposes. If it is done correct it can be safe and practical.

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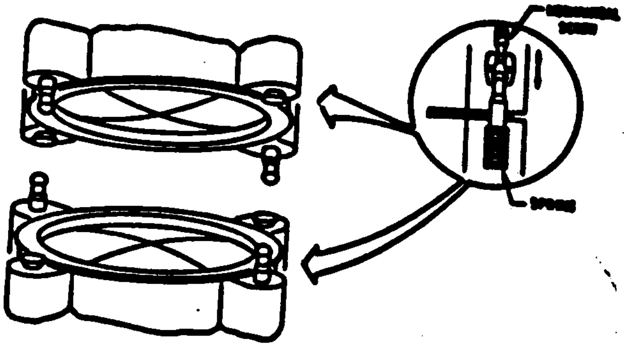
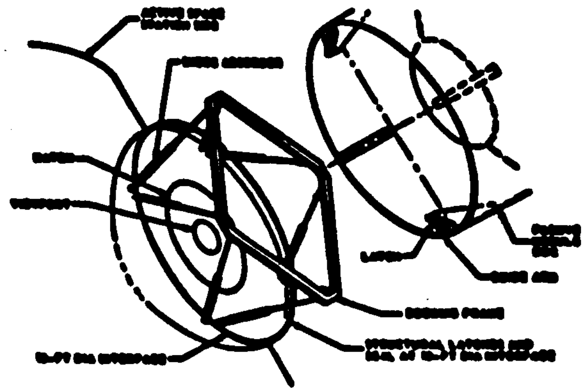
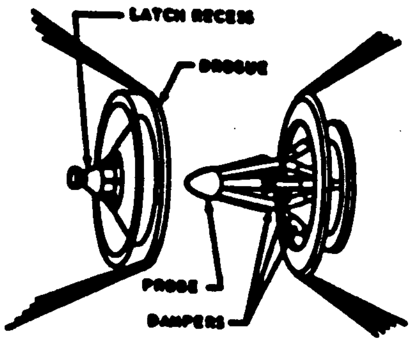


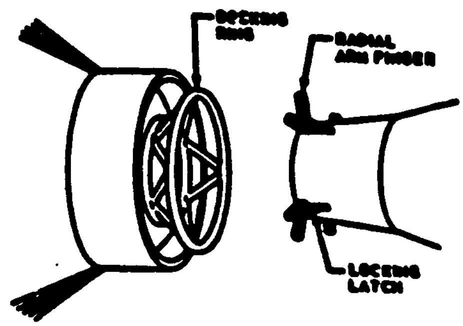
bisexual docking mechanism concept



SQUARE RING AND GUIDE/LATCH DOCKING MECHANISM CONCEPT

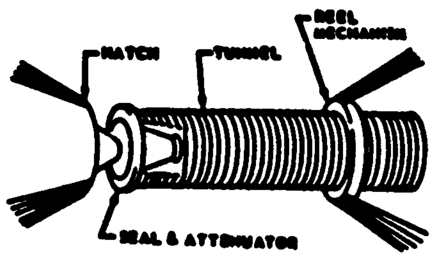


PROBE & DROGUE SYSTEM

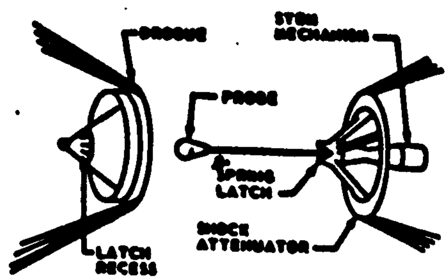


RING & FINGER SYSTEM

IMPACT DOCKING SYSTEMS



INFLATABLE TUNNEL SYSTEM



STEM & CABLE SYSTEM

NON-IMPACT DOCKING SYSTEMS

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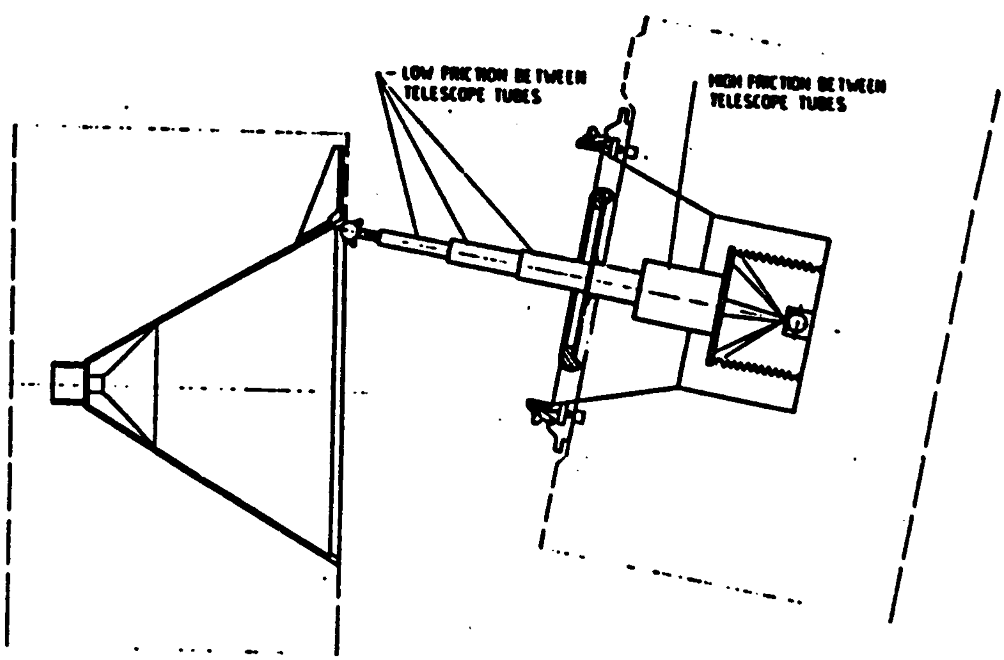

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Chapter 12: Extravehicular Activity

Mike Godfrey

April 8, 1987

12.1 Definition of Topic

Extravehicular Activity (EVA) is the work done outside of the Variable Gravity Facility (VGF) while in space.

12.2 Background Information

The VGF must provide an EVA capability for: maintenance, experiments, and emergencies. The VGF will need to develop these three EVA capabilities because of the many unknowns VGF will challenge.

The need for maintenance and emergency capability on VGF is important. Provisions must be made to enable the crew to perform an unplanned EVA incase of a systems failure.

The VGF is the first manned orbital platform specifically designed to do variable gravity experiments. No EVA has ever been done on a rotating platform before: Because of this, all EVA done on the VGF should be considered experimental and dangerous. Thus the need for a experimental EVA capability.

12.3 Proposed Mission Requirements

VGF must have redundant EVA equipment and systems.

The safety of the crew must be put first.

EVA equipment must be designed and integrated to handle the different stresses and work loads produced by VGF.

The EVA equipment must be designed and used in such a way as to provide peak mission efficiency.

12.4 Proposed Method of Meeting Mission Requirements

VGF must have one EVA airlock on all three modules in order to maintain EVA redundancy.

At each EVA airlock there will be an EMU (Extravehicular Mobility Unit) service station similar to that of the space station (12005, p. 8).

The EMU service station will interface with the ECLSS (Environmental Control/Life Support System) of the VGF. The service station will regenerate the EMU life support module (12005, p. 8).

At each EMU station there will be one EMU and one MMU (Manned Maneuvering Unit).

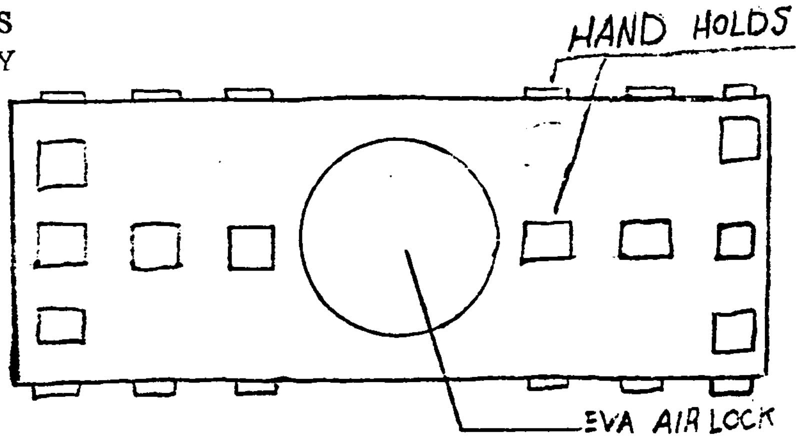
To minimize EVA mass and repair costs, there will be only one EVA repair station. The repair station will be part of the center module service station. The center module service station will in turn be placed on or near the docking module. The docking module will be used as the center module's EVA airlock.

The VGF EMU and MMU will be simular to that used on the space station and space shuttle.

There will be a total of four EMU/MMUs. One EMU and one MMU will be stationed in the service station of both outer VGF modules. The remaining two EMU/MMUs will be stationed in the docking module.

EVA should be planned to provide the EVA crew with adequate food and drink for 8 hours (38 oz. H2O and 750 calories of food), with adequate break time (12006, p. 4.4.9-4.4.9.3.4).

With each EMU there will be a safety harness simular to that of a mountain climber. The harness will have clips that can be attatched to brackets on the outer hull of all three modules of the VGF and its solid framwork or tethers (12001, p. 60-68). These brackets will be part of a frame work of hand holds that will be placed two feet apart on the outer hull. The tether to be used will be at least as long as the VGF modules. There will be two brackets on each hand hold, and the hand holds will be in groups of four in a formation of a square. Refer to diagram on page 4.



Each EVA will consist of two astronauts fully suited. While one astronaut is working, the other is ready to assist the first in case of an emergency. The two astronauts take turns working during the EVA. This buddy system will enhance the safety of the EVA and the efficiency of the crew (12005, p. 60-68).

Each EVA will be monitored via radio and television by a crewman inside the VGF to assist the EVA crew with needed information and coordinate the proper procedures in case of an emergency. The monitor will also aid in EVA data processing and integration in real time (12004, p. 7).

Because of the danger involved with EVA done on VGF, The crew has the final say on the when and how of the EVA if they decide to perform it. Also, the astronauts performing the EVA should be incouraged to develop new EVA techniques and procedures while in orbit.

12.4.1 Discussion of Proposed Method

advantages

Each VGF module will have independent EVA systems, and equipment. This will give the crew of one module to perform an emergency EVA if it is "cut off" from the center module.

The cost of EVA equipment and support systems will be acceptable because most, if not all, of the equipment is standardized and "off the shelf".

The "buddy system" will insure the safety of the EVA crew during EVA.

The brackets and hand holds on the outer hull of VGF can be used at a minimum of cost and mass.

The crew will have full control of the EVA. This will give the crew the freedom to choose which EVA is needed and which is not.

disadvantages

The crewmen who monitor the EVA will have a limited field of view. This problem can be partialy solved by the proper positioning of TV cameras.

The EVA crew are at a risk of getting tangled in their own tethers if they are not careful.

The crew will have full control of the EVA. This could lead to discontentment between the crew and Mission Control.

12.5 The Use of Robotics in EVA

advantages

Robots can be designed and programed to do EVA work efficiently.

The use of EVA robotics can be designed and inegrated to work independently of human control if need be. (12002, p. 7.14-77.20).

The EVA robotics mainframe could be integrated into the VGF flight computer and communications to use up-to-date EVA data from the ground in real time (12004, p.7).

disadvantages

In case of robotic failure while in EVA, a crewman will have to retrieve the broken robot.

Current robotics and artificial intelegence is not developed enough to replace humans in EVA (12002 p. 7.14-7.20).

12.6 No EVA

advantages

This is the cheapest and most simplistic EVA system known.

disadvantages

VGF will not be able to help itself in an emergeny.

12.7 EVA done only from Shuttle

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advantages

The VGF will need no EVA equipment or suport systems. Thus giving room for more equipment and suplies.

disadvantages

The VGF will have no emergency EVA capability. VGF will be dependent on the shuttle for all EVA. This would leave NASA and the crew of VGF "caught with their pants down" in an emergency when the shuttle is not accessible.

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Chapter 13

BODY STORAGE IN CASE OF DEATH

Paul Novak, Kay Pues, Charles Simons, Michael Trost, Charles Tye

.1 Definition of Topic

Body storage considers the options available regarding the storage or disposal of human remains after a fatal illness or accident aboard the variable gravity facility (vgf).

.2 Questions

1. What to do with the body of a person who died aboard the variable gravity space facility?
2. Do you store or dispose of the body?
3. If storage is chosen, what effect does the storage method and location have on the other vgf inhabitants?
   - ex. health considerations
   - psychological considerations
4. If disposal is chosen, should the body be released into space?
5. What are the religious and legal implications of body storage and disposal in space?
6. What cultural and international differences are there in customs surrounding death and burial?
7. If a body is stored outside the vgf, will it "cook" if not shielded from solar radiation or freeze solid if completely isolated from solar radiation?
8. Should a will be required, stating burial preference, before departing Earth?
9. Do you plan a storage area for one, or several, bodies?
10. Will any body preparation, or autopsies, be done while in space?

.6 Design Requirements

A storage compartment designed for storing human bodies should be secured (locked), air tight, under reduced (negative) pressure, and refrigerated(frozen). In event of death, if the body can be recovered without risk to other personnel (for example, an accident occuring external to the vgf), the body is to be recovered, placed in a body bag, sealed, and stored in the compartment described above or in an external (pressurized) compartment. The body will then be shipped back to Earth on the next shuttle for autopsy and release to next of kin.

If body disposal, rather than storage, is chosen the method of storage before disposal will be identical. In addition, a suitable "coffin" must be designed if the body is to be released into space. Disposal options include releasing the body into space through an airlock system, cremating the body and releasing its ashes into space, or releasing the body into space and boosting it toward the sun.

.7 Expanded Design Requirements

When considering body storage you must take into account how the person died. The type of death may dictate special storage requirements such as leadlined bodybags for radiation deaths. Other cases which may need special treatment include: contagious diseases, decompression, and trauma. Another consideration is the size of storage area needed, how many bodies are being stored and for how long, whether the compartment needs gravity, and should the storage compartment be isolated from the rest of the vgf.

.4 Unanswered Questions

Since a death requiring storage or disposal of human remains in space has yet to occur most questions remain unanswered.

.5 Obtaining data and information

Possible sources of information about shielding human remains from solar radiation would be available from space suit manufacturers. More information could also be obtained from actually performing experiments on cadavers, or tissue cultures, in space.

Alternative sources would be mortuary science, legal precedents on unusual burial requests (for example, scattering of ashes), legal requirements concerning accidental deaths and autopsies, maritime laws and traditions concerning burial at sea, and cruise lines specializing in cruises for senior citizens (what preparations are made in case one dies during a cruise?).

.8 Solutions

Options on body storage and disposal will, whenever possible, be made by an individual prior to departing Earth. These wishes will be honored unless unusual circumstances associated with the death (for example, a new space disease is suspected) and an autopsy is required on Earth for research purposes.

If body disposal, rather than storage, is chosen options include releasing the body into space through an airlock system, cremation and release of the ashes, or releasing the body into space and boosting it toward the sun. In the absence of a will stating otherwise, it is highly recommended the body be released into space and projected at Earth so it burns-up on re-entry into the atmosphere.

If the body is being stored and returned to Earth an option is storing it in a compartment (described above) located in the zero-g, center module of the vgf. Bodybags would float in the compartment and be anchored to the wall by cables at each end. The compartment's insulation could be reduced to lower the temperature for preserving the body. By doing this the body is isolated from the crew and removes the health and psychological problems of storing it in the main modules.

.9 Viability

.3 References

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Chapter 14 Food, Equipment and Galley Layout Design

By
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Pair C
4-29-87

14.1 Definition of Topic:

The goal of the Variable Gravity Facility (V.G.F.) food system is to support the nutritional needs of the V.G.F. crew with nutritious meals without sacrificing weight from the shuttle or the orbiter payloads. Also time in space is precious in a very real and economic sense; cooking, food preparation, storage, and eating must be efficient to allow as much time as possible for mission activates. However the crew of the V.G.F. will be dealing with a whole new concept of mission activates; they now will have the time to find, fix, prepare, eat and clean up. There will be no rush due to the long mission durations. Yet time should not be wasted but spent in the most efficient fashion.

14.2 Background Information:

In space food takes on a importance far beyond what it is in ordinary circumstances. This is even true of people who are usually indifferent to food. The V.G.F. crew will use food to get rid of boredom, frustration, anger, tension and as a reward or celebration. In a sensory deprived places were there will be plenty of undisputed tension, lots of pressure and with little or no escape; and with few physical pleasures, food will act as a psychological function as a pacifier and tension releaser(14003,p.185). In space the question of food is further complicated by a degraded sense of smell and taste. Onboard the V.G.F. under artificial gravity this problem wont be so extensive.

Probably the most neglected role in society and already recognized in space is that of NURTURE - a persons unacknowledged contribution to society helps makes human life human and makes home home. This nurture is neglected in current space psychology crews. The crew of the V.G.F. has the ability to make a space mission a pleasant kind of living rather then a extended type of camping trip. Aboard the V.G.F. the cook along with the commander should have the highest status. Food has such fundamental associations with home and family. It would be foolish to rely indefinitely on ready to eat, preprepared meals when one can have a morale boosting cook aboard to surprise, delight and nurish all at once! (Even this responsibility could be shared by all the crew members, taking their turn cooking and preparing foods.) Since food is such a principal morale booster special attention will be paid to menu variation, attraction, presentation and abundance aboard the V.G.F.

14. 3 Proposed mission requirements :

All systems onboard the V.G.F. must meet the requirements for stability to temperature, pressure, decompressure, vibration, zero g's, corrosion, acceleration and normal use by the crew. Operational life of the galley food preparation system. Shall be a minimum of 5 years. Full testing of all systems shall be completed before being installed. The following material is based on a three member crew for each capsule for a combined crew total of six if the two capsule concept design is used There will be one galley per each capsule and each galley will require the following for each galley system. The food system aboard the Variable Gravity Facility will be designed to provide meals that are both nutritious and appetizing yet they must not be time consuming. Meals should take only 20 minutes or less to prepare, however there will be some food items that will just naturally take longer.

The galley shall provide a centralized location for preforming all food related functions (except dining) within the V.G.F. There will be portions of the galley to provide for food stowage, trash handling and stowage, hot and cold water dispensers, microwave oven, intergral heating oven, preparation equipment and accessories, utensils, wipes and eating and dining accessories. The galley shall be designed to permit minimum meal preparation and clean up time in various gravity levels ranging from zero to one (0-1) G along with ease of servicing and maintenance of the facility. Food capacity required will be for 120 man-days capability plus a 30 man-days worth of contingency food for each crew member. The galley shall be sized to accommodate the majority of this quantity of food. And the rest will be stored in food lockers, located through out the V.G.F. And it will be large enough for a crew of three. The weight of the food should not be more than 4320 lbs. This allows 4.8 lbs of food per person per day for a total crew of six; and a 0.4 % packaging material weight. The food will be comprised of bulk food items, bulk beverages, rehydratable food items, ready-to-eat (RTE) Food items and condiments. Also there will be a separate amount of Contingencey food that will be military type emergency rations. All parishable food items will be transported to the V.G.F. in temperature controlled cargo pods that will be stowed in the shuttle cargo bay.

14.4 Proposed Method of Meeting Mission Requirements :

Food for the V.G.F. will be transported by the shuttle every 90 days or sooner if a launch permits. During this time frame restocking of the food supply should occur if it does not occur there is a built in 30 day allowance for the crew members to live on. And if in this time period there still has not been a launch there is a additional 30 days worth of contingency emergency type rations. To transfer perishable food items from earth to the V.G.F. a bulk food resupply cargo pod shall be needed. Resupply of bulk dried food items will pose no problems in stowage it will only be a simple storage space container will be required; however resupply of frozen and perishable food items will require the use of the cargo pod. The pod basically a theromoelectric freezer that will run off electricity The freezer portion is to be located inside and it will have double polyimed honey-comb insulated walls with multiple layer vacuum insulation. A commerical theromelectric module can be installed so that the cold end will be in intimate contact with the lauminum wall liner of the freezer cavity and that the hot end will terminate in a air cooled heat exchanger heat sink. The pods outside shell will be constructed of light weight aluminum. The cargo pod will keep the food items at a variety of temperatures ranging from 0°F to 42°F so that bulk food items will stay fresh during transport. The bulk food items will be packaged and arranged to fit for the transfer. The pod should be able to hold at least 300 lbs. (earth pounds) of food and will require two crew members to transfer it about. For the food preparation V.G.F. crew meals will consist of bulk foods being prepared to individual menu amounts and then consumed. Meals may consist of combinations of rehydratables, ready-to-eat (RTE) and bulk food items. The bulk food items will provide the basic main course and side dishes for each meal; they will be supplemented by the rehydratables and by the RTE's and beverages. Bulk foods will be large food items packaged by size and weight. Such as meats, breads, cereals, and preprocessed prepared and cooked foods on earth which just needs to reheated and served.

Onboard there will be hot and cold water dispensers with temperatures that range from 67° C for the hottest and 07° C for the coldest and it will be adjustable for in between the temperatures. The dispensers will allow the crew to mix liquids and to prepare dehydrated food items(14002, p.2). The hot water source shall provide the required rehydration water in quantity and temperature control. The hot and cold water shall be dispensed by a crewman actuated devices that mate with the insertion septum device on the food, or drink package. The dispensers will be capable of dispensing up to 12 +/- 0.1 ounces of water at any one usages; and it is to be adjustable in increments of 1/2 ounce. The dispenser shall have a visual indication of the amount of water to be dispensed. The dispenser probe shall be designed to puncture the beverage package material or the rehydratable package without damage to the probe or the package and the flow of the preselected amount of water. The dispenser design shall be that it will not leak water into the galley cabin. And the dispensers shall minimize water temperature excursion between uses(14005, p.8). Each crewmember shall be provided with a reusable drink glass to mate with the the water dispenser probe. Along with a 12 oz. reuseable beverage glass that is designed to be used in various gravity levels. (see figure attached)

After rehydration the hot food items shall be maintained at a desirable temperature by a galley holding oven, until the remainder of the meal preparation is completed. The hot food serving temperature shall be around 135-145° F. The RTE's will be food in there natural state or food that is already prepared and is ready to eat with little or no preparation needed. The proposed beverage items will be of bulk reconstuted liquid or powder, ready to mix ; just add water type and shall be served according to the amount desired.

Also onboard the V.G.F. their will be a microwave oven to cook large and small bulk items in which the intergrated heating system will not be able to cook due to long cooking times and higher cooking temperatures The microwave should have a built-in carousel that turns the food for even cooking, a temperature probe, a weight-defrost system to thaw frozen foods. It also should have variable power settings to allow different temperatures. And a off/ on switch with all selection positions being clearly indicated for quick visual references. It should be large enough with at least a 1.6 cu f.t. interior. This is recommended because this size will accommodate large bulky items. Also microware will be required the on V.G.F. such as microwaveable plates, bowels, cups and glasses along with service trays that must be included to cook and serve the food on. By using a microwave for cooking and reheating leftovers, it will be extremely energy efficient.

The V.G.F. will include onboard several types of long-term food storage devices including a 23.5 c.u. ft. deep freeze to store bulk meats and other foods that need to be kept frozen for extended periods of time . There will be included onboard two refrigerators of 23.5 c.u. ft. and one of 14 c.u. ft. These will allow the crew enough space to keep and preserve precooked and leftover foods and beverages. There will be a computer to use for food planning of a 120 day menus that need to be calculated since food management systems are to be based on 120 day capability with a 30 day emergency rations.

A meal assembly area is to be located in the center section of the galley and it will be utilized to enable crew members to prepare and assemble meals. Total meals for the entire crew of three shall be prepared and servered at one time. The galley shall contain several integral work areas to support food and beverage preparation requirements along with inbetween meals periods, and to support basic meal assembly procedures. The food packaging requirements for beverages will be contained in a light weight plastic container of at least one gallon or more volume; and it will be designed to allow the crew to pour the substance into a mixing container to be added with water. Also there will be onboard a beverage drink package consisting of a hermetically sealed flexible plastic container with a intergral septum material that is punctured for water insertion. Warm or cold water may be used. It will be used when the V.G.F. is at a lower gravity operational levels. When folded and stowed, each beverage pack is essentially rectangular with dimensions of 3.5 x 5.0 x 0.28 inches overall (14005, p.3).

The majority of the rehydratable food items will be packaged as bulk rehydratable food items. However there will be a small amount of the current type in use developed under N.A.S.A. contract NAS 9-13138. This package consists of a semi-rigid saucer-like base to which is affixed a flexible plastic cover folded and sealed to the base. Within the base is a septum material for inserting a water dispensing needle for hot or cold rehydration. The package is vacuum packed, and when stowed all rehydratables are 4 x 4 x 1.03 inches overall(14005, p.4). The RTE's foods will be packed so that there will be no damage or spoilage durning storage and handing and then in individual plastic overwrapings. The bulk food items will be packaged according to substance; meats will be packaged in at least 5 lb. packages and will be kept frozen until they are consumed, cereals will be packaged in heavy gaged plastic bags that are zip-locked sealable, the same type of packaging will be required for breads except that they will have a preformed custom fit. The condiments (salt, pepper, spices, sauces, catsup, mustard etc.) will be provided in bulk containers along with smaller serving containers. And the contingency food will provide emergency rations in the event of a resupply launch is delayed. The Air Force emergency rations will be used in this event the emergency ration basic dimensions are of 2.12 x 3.25 x 3.75 (14005,p.4). The food will be preselected and planned by the ground crew with the consent of V.G.F. crews tastes and compatibility Computers will be used to help the crew keep track of the inventory and to assist in planning meals. Food shall be stored on the V.G.F. such that packages for each meal can be readily accessed and identified. Removal of a food item shall not be encumbered by other food items. The food removal sequence shall be in accordance with the preselected menu plan. The intergral oven shall have an off-on switch and shall clearly indicate its selection position. The oven shall have a preheat operating temperature control and will be provided with a temperature gauge to provide visual assurance to the crewmembers of oven operating conditions. Utensils shall be provided for each crewmember. There will be 12 sets of reusable full size utensils each consisting of spoons, forks, knifes and they shall be stored in the galley. There will be planning done on the ground; to determine the most efficient use of food items so that food items dont generate a great deal of refuse which can create a potential storage problem for garbage. Food going aboard the V.G.F. must have a high nutrient and energy values with low residue content as possible. And they also have to stand up well under stress and shocks of launch, weightlessness, different gravity levels and a oxygen nitrogen atmosphere of the crafts(14002,p.2).

After a meal the empty food containers will be compacted in a trash compactor onboard the V.G.F. The waste disposal system will have a top loading plexi glass door with a vacuum seal; and will be temperature controlled at approximately 28°F. This will prevent the majority of bacterial growth from affecting the crew. The garbage will be kept in a large 34" X 30" heavy duty polyethylene bags. The disposal system will be capable of compling the trash by having hydraulic walls that press down on the garbage by the use of a hydralic pump. Its cooling system will be similar to a conventional freezer. Also to be incorporated into it is a bacterial growth and odor spray disinfectant, which will be sprayed dally into the compactor. This function will be built into the equipment and there will be a reservoir for storing the disenfectent that will have to be filled weekly. And then once a week or when ever needed it will be emptied and placed in a large mesh net outside the V.G.F. through E.V.A. This will allow a build up of recycleable materials that can be used for future use or processing in space and will save money by not having to transport them up in the future(14004). There will be a food storage locations incorporated into the V.G.F. and in the galley food storage lockers will be installed They also will have a temperature controled environment for food item spoilage control.

14.4.1 Discussion of Proposed Method :

The food preparation system will be designed using an intergral heating system. This system features an entirely new concept of electronic food warming. No gas/flame, no electronic rods, no thermostats and radiation. The system shall operate on electricity and by doing so it will allow the heat to go directly to the food that is going to be prepared. Heat is not to be wasted by heating the oven walls and surrounding air. The designed efficiency of the intergral heating system is 90 percent plus efficient, then compared to an conventional oven of 30 to 50 percent (140001, p.67). Some type of protection screen will need to be deployed around the microwave oven to protect scientific equipment and communications and the crew from the possibility of leaking radiation/microwaves in case of a accident. One problem that might exist with using microwaves is that of heat conduction were some foods have hot and cold spots internally. This problem should be taken care of through the use of a rotating carosel in which the foods will get even exposure of the microwaves. The cargo pod can also be used to return materials and since its temperature controled it could be used for the return of speciments and cultures and supply of materials of various laboratory experiments One advantage of the cargo pod will have is that it can be used as a portable freezer unit or a refrigerator; and it also will serve as a back up system for the galley freezer and refrigerators.

14.4.2 Weight Estimate of Proposed Method :

The food once resupplied will be enough to last a crew of 6; for 150 days this is 120 days for the expectancy of the next arriving transport and a 30 day safety factor. The weight of the food should not be more than 4320 lbs. This allows 4.8 lbs. of food per person per day and allows a 0.4 % weight in packaging material (172.8 lbs). And if the arrival schedule is met and on time, only 3456 lbs. of food is needed as long as there is no spoilage of food, that is to be maintained for the safety factor. This amount also includes the weight of the packaging material and the food/ beverage.

14.5 Alternate Methods of Meeting Mission Requirements:

Solar reflectors may be used to heat foods. Also gas or fuels may be used to cook foods.

14.5.1

Some future plans should be made to set aside some area for a space garden or CELLS (closed ecological life support system). Such an agricultural project will have to be carefully planned, however in order to produced the most food for the least amount of space.

14.5.2

For the cargo pods ammonia, fuel or gas can be used along with dry ice or frozen blocks of hydro carbon to keep its contents at various temperatures

14.5.3

Reusable containers will maximize practical utilization and save on weight. They should be made of standard off the shelf, low cost metal or plastic to be used as the containers.

14. 6 Discussion of Unresolved Issues:

One problem that might exist with using microwaves is that of heat conduction were some foods have hot and cold spots internally. This problem should be taken care of through the use of a rotating carosel in which the foods will get even exposure of the microwaves. The other known problem might be that of interference with sensitive instruments. So by building in an protective screen around the the microwave system this effect should be eliminated. One item to be looked into is that of bulk vs. dehydrated there would be a substanal weight saving but the crew members might reject the flavors and tastes of the all dehydrated food items. All the equipment and eating utensils need to be designed to be useful at several gravity levels. Also there has to be some studies on the power levels and type of all the galley equipment power requirements. An other problem is that of long term garbage disposal; and what should be done with it? One more thing that needs to be looked into is that of washing or cleaning of dishes and cooking utensils.

14.7 Summary :

All the galley equipment aboard the V.G.F. will have to be designed and tested to meet the requirements of being able to function properly in multiple gravity levels of 0-1 g. There will be a great need to develope new tools and machines to produce some of the equipment. The rest of the equipment will be ordinary every day use material to cut down on cost.

Also there will have to be a major redesign in the cooking equipment and eating utensils that will adaptable to various levels of gravity conditions And that the galley equipment sizes and dimensions need to determined according to crew size and the type of design the V.G.F. is to be used.

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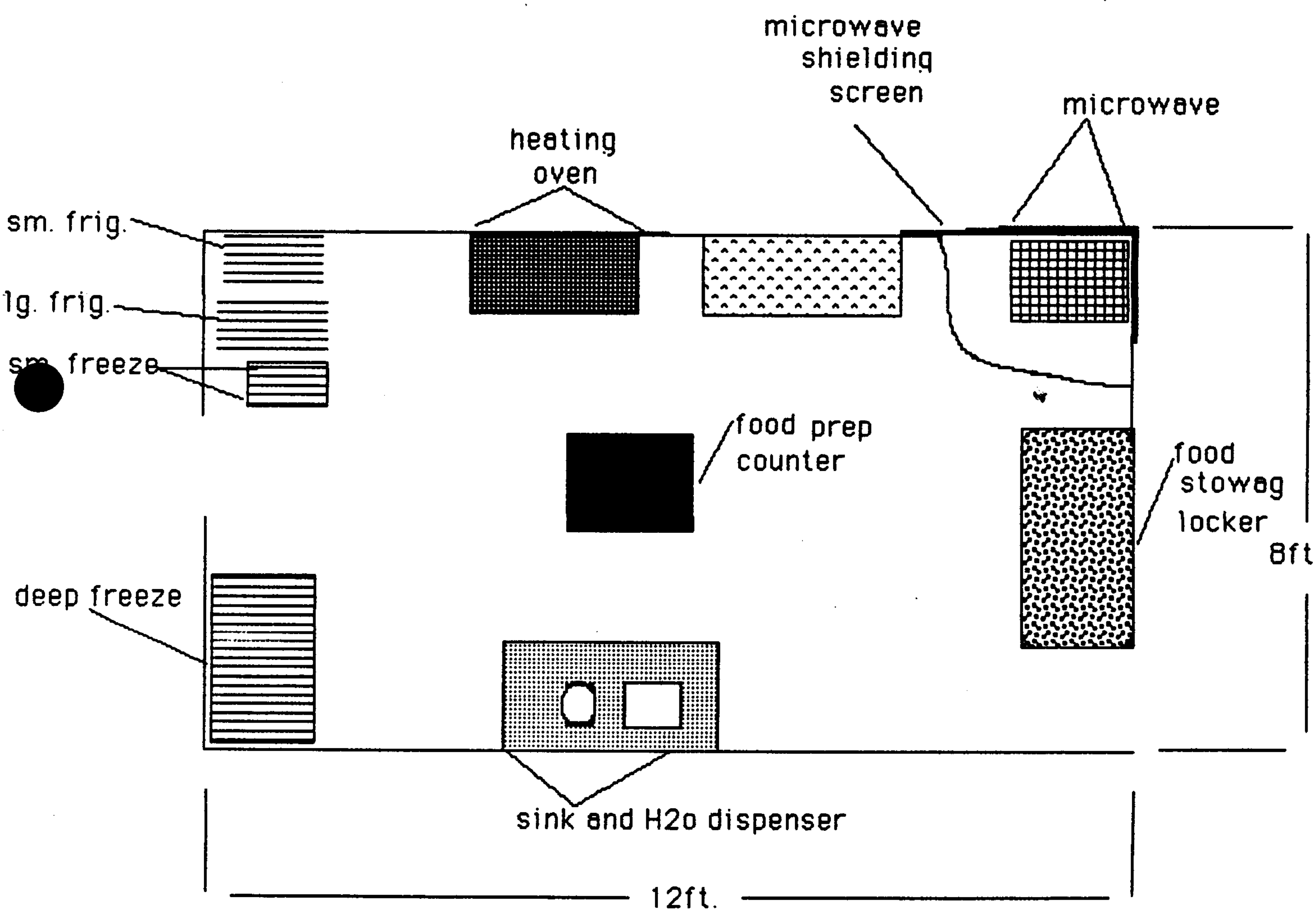
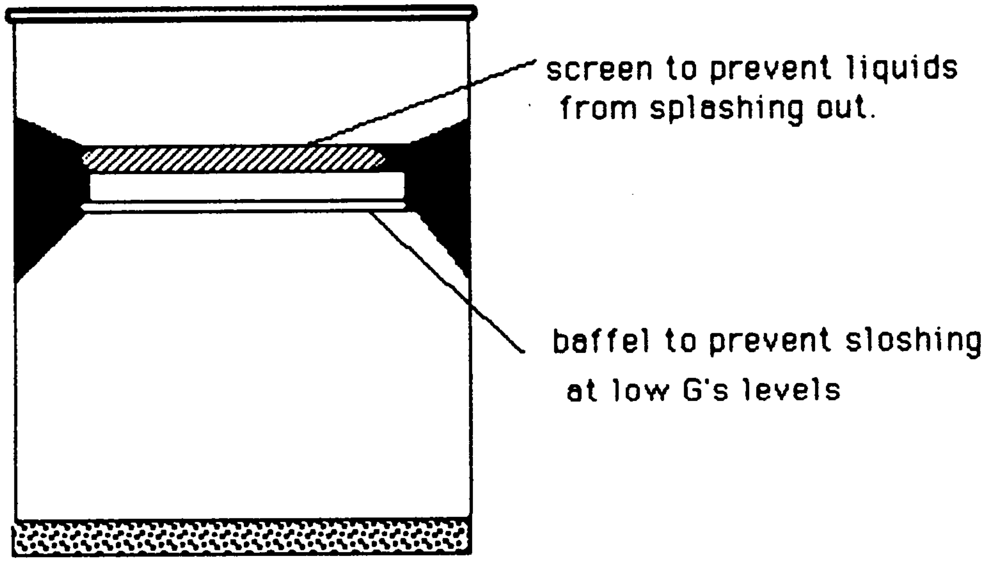
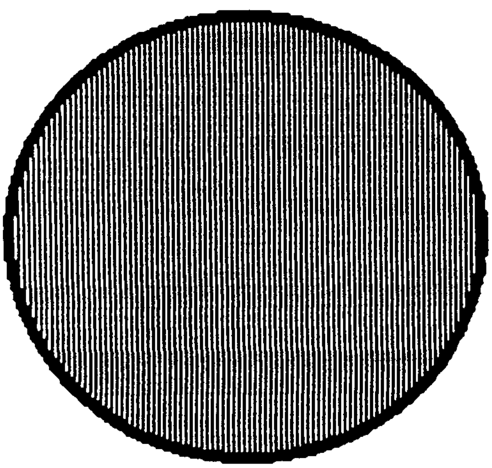
GALLEY LAYOUT DESIGN



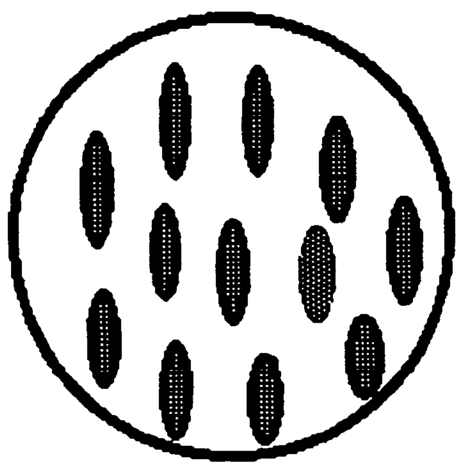
12 oz.
Beverage
Glass



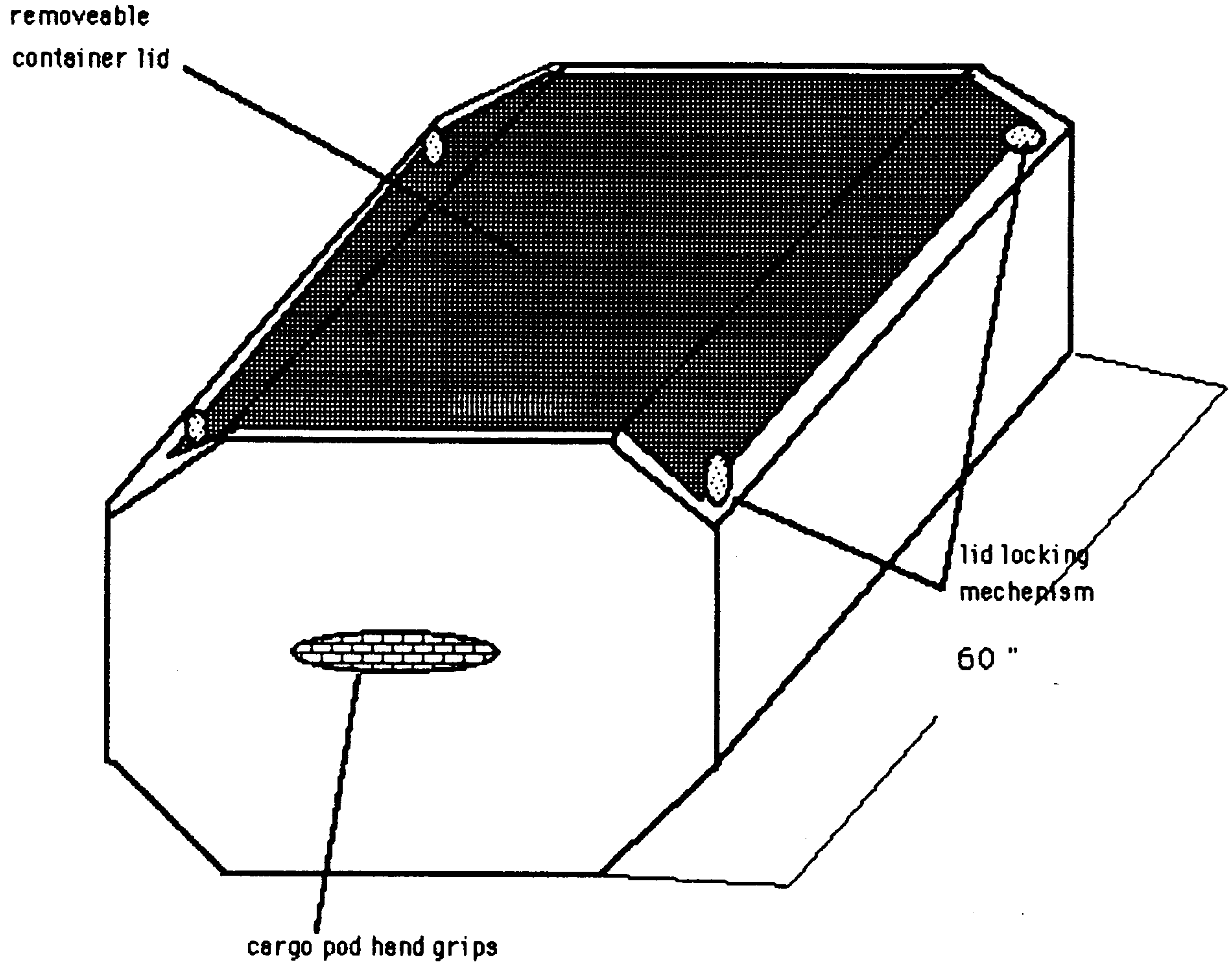
inside view
of screen

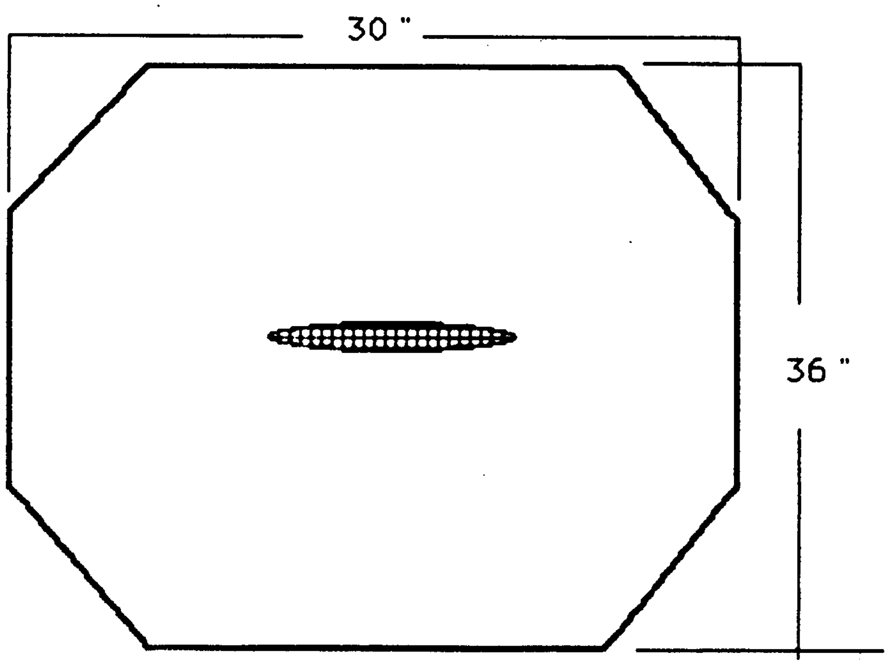


inside view
of baffel



The Bulk Food Resupply Cargo Pod





CHAPTER 15

ENTERTAINMENT AND RECREATION

Rob Volden
Jerry Petersburg

4/29/87

15.1 Definition of Topic

Recreation and entertainment activities aboard the variable gravity facility (VGF) will be those activities, either scheduled or spontaneous, which will allow the crew to relax and enjoy their stay in space. Since stay times may well be as long as three years, activities must be available to overcome boredom and isolation effects. This report will investigate what types of recreational activities will be most beneficial for space station crew members in terms of increased morale, physical and psychological health, and cost.

15.2 Background Information and Assumptions

Throughout the history of manned spaceflight in the U.S. the flights have traditionally been of short duration. Because this has been the case, the crews have worked a strenuous schedule, often working 12-14 hours per day. As the length of missions increases with the coming of the age of the space station, entertainment and recreation time will become more important. This idea is parallel with the same occurrence on the ground. Early settlers of America were required to work very long days just to survive, but as people settled down for longer times and with the invention of many labor-saving devices, more leisure time has become available to us.

As stay times aboard the variable gravity facility increase to over six months, not only will time be available for recreation and entertainment, but it is very important to use time for recreation in order to maintain crew morale and health. "The inclusion of appropriate leisure time equipment and carefully planned mission timelines can help to alleviate psychological problems which could arise as a result of the relative isolation and physical restriction imposed by the spacecraft environment" (15005, p. 4-15).

Many people think of recreation as a "get away" to help forget about troubles of daily life. Because of the nature of the facility, an actual escape is impossible. However, it may be important to have a separate recreation area which would give the crew a feeling of getting away (15001, p. 76).

Although there will be some experimental work for the crew to study during their stay, only a small portion of their day is likely to be filled with work. Possible work activities include the following: 1) Making the necessary physiological measurements, 2) Researching other biological systems (plants, insects, bacteria, sponges, etc.), 3) Researching equipment needed for fluid handling, 4) Studying mixing and sedimentation rates and other fluid dynamics, and

5) Studying recreational activities at mid-G levels (ping-pong, trampolines, ballet dancing).

Isolation studies show that if there are specific tasks to be performed, then work is the crew's main focus. They show little interest in leisure and tend to hoard workloads in an attempt to succeed. On the other hand, if no work is required, they show no special interest in either work or recreation. They tend to concentrate only on the short term goal of surviving the confinement (15001, p. 75). "Where work is adequate and satisfactory, most other parameters of the setting have less effect on overall performance and satisfaction. Where the work is less adequate, other parameters may become more critical" (15008, p. 41).

In most cases people going into confinement plan to use their leisure time constructively. Often crews are selected based on their ability to use their leisure time effectively. These goals are not necessarily accomplished. Research shows that Antarctic crews often pursue escapist fundamental leisure activities despite constructive goals. Whereas, crews of nuclear submarines tend to do the opposite often increasing the complexity of their reading as the dive goes on (15001, p. 79) (15002, p. 486).

Several surveys have shown the preferred recreational activities of potential space crews. E.E. Eddowes surveyed male professional personnel of an industrial aerospace organization. Following is a rank ordering of equipment desired for a hypothetical space journey (15002, p.486).

1. Books
2. Playing cards
3. Chess
4. Musical instruments
5. Record equipment
6. Handicraft equipment
7. Art supplies
8. Writing supplies
9. Athletic equipment
10. Puzzles and games

Karnes, Thomas, and Loudis (15003) surveyed test pilots, military pilots, and aerospace engineers and scientists. They found the following preferences (15003, p. 53).

1. Active recreation
   - -physical-exercise equipment
   - -sports equipment
2. Passive entertainment
   - -viewports in spacecraft
   - -books
   - -hi-fi, record, or tape players
   - -am, fm radio
   - -magazines
   - -newspapers
   - -television sets
3. Communication
   - -radio equipment for personal communication
   - -writing supplies
4. Games
   - -playing cards
   - -board games
   - -dice
5. Hobbies
   - -photographic equipment
   - -model-building kits
   - -musical instruments
   - -painting and drawing supplies
   - -stamp and coin collecting equipment

Astronauts listed the following off-duty and relaxation preferences (15007, p. 181).

1. Activity associated with work
2. Reading
3. Physical exercise
4. Studying

5. Sports
6. Listening to records
7. Family associated activity
8. Watching TV or movies
9. Seclusion
10.5 Composition on technical themes
10.5 Rest, relaxing, doing nothing

The Russians have had more experience in long duration flights than we have. They have used the following recreational activities (15001, p. 79).

-live concerts broadcast to space
-piped-in music and news
-two-way radio/video communication with family and friends
-letters and presents from home
-horror movies to relieve depression

15.3 Proposed Mission Requirements

1. Recreation equipment should be made available according to the desires of the crew.
2. Efforts should be made to adapt earth-based activities so they can be practiced aboard the station.
3. Association with people on the ground through communication is important to overcome isolation.

15.4 Proposed Method of Meeting Mission Requirements

"... the most important factor in the enjoyment of leisure time activities is freedom of choice. That is, people enjoy their leisure time activities because they choose those activities. Therefore, the development of off-duty concepts for future space missions should be made with due consideration given to preferences of the crew members; that is, crew acceptance must be the primary goal in the selection of off-duty concepts" (15005, p. 4-15). One school of thought is to promote passive/ noninteractive recreational activities.

We decided that passive recreational activities would be most beneficial aboard the VGF. We reached this conclusion based on crew preferences for these activities and also a desire to prevent intense competition among the crew. The following activities will be used: 1) Radio will be used extensively for recreation. A secure communications link will be required for family communication. Music can be broadcast using a juke-box system allowing the crew to select the songs played. 2) A large screen TV will be required for nightly movies. 3) Reading material can be provided in the form of reduced microfilm. 4) Rope, small magnets, and small balls should be provided for educational experiments. 5) A telescope and extra film for use in the mission camera should be provided for use by earth-watching astronauts.

15.4.1 Discussion of Proposed Method: Advantages and Disadvantages

Some evidence shows that passive entertainment is more popular in confinement (15001, p. 76). One reason for this could be because normal leisure activities tend to be more passive. Active activities would then require the crew to develop new interests (15001, p. 76). Another reason could be a desire to be nonconflicting. If this is the case computer games or games against people on the ground could be utilized (15001, p. 78). We recommend noncompetitive activities because competition and cooperation have been shown to be mutually exclusive events. Competition also leads to suspicion and contempt (15009, p. 15).

Radio has many uses as a recreational device. It can be used for communication with family, news, and music. In order to maintain private conversations between crew members and family, a "scrambled" communications link is necessary (15005, p. 4-20). Earth orientation or keeping up with the news and activities on earth is a very important factor of radio (15005, p. 4-19). Music can be used not only as leisure but also in the background to reduce the boredom of monotonous activities. It is important to account for different musical tastes among the crew. A "juke-box" system similar to those used on submarines could be used (15002, p. 486). This would allow the crew to hear the songs that they want to, without the boring repetition of piped-in music.

Television and movies would allow the crew to gather together. Movies could be shown at specific times as is done on submarines (15002, p. 487). Movies are usually shown every night in the Antarctica, and we think that a nightly gathering to watch a movie would be good aboard the VGF. There is some evidence that people attending movies, as opposed to those watching the same movie on a TV, experience greater involvement or satisfaction. Some of this effect is probably due to the presence of the audience, and some is due to the larger more life-like screen and sound system (Anonymous). A large screen entertainment facility with hi-fidelity stereo sound capabilities will provide these benefits. This equipment could have multiple uses when not actually used for movies, for example as a normal CRT. Calvin (15007) suggests that the equipment could be used to show scenes of earth at different times of day and at different seasons, according to the home characteristics of the astronauts. Such equipment should help to alleviate feelings of isolation expressed by many astronauts.

Reading provides a wide range of variety to accommodate for differences among the crew. A system of reducing written material such as microfilm must be used. It must be designed to provide minimum eye strain and ease of reading (15002, p. 487).

There are many opportunities for educational activities aboard the variable gravity facility. As Leonov and Lebedev (15006) suggest, crew members who are knowledgeable in a specialty could conduct lectures and demonstrations for the rest of the crew. This is common in antarctic stations. Also crew members could perform interesting experiments about varying gravity levels with such items as rope, magnets, balls, etc. (15005, p.4-21).

Throughout the history of spaceflight, earth-watching and looking out windows has been the main leisure activity in both the US and Soviet programs. American crews requested more windows in more locations throughout the ship (15004, p. 28). The provision of a telescope and extra film for personal use in the mission camera will enhance the crew's earth-watching (15005, p. 4-20).

15.4.2 Weight estimate of Proposed Method

1. Scrambler/Unscrambler -- 1 lb. using voice transmission link (15005).
2. Reel-to-reel tape -- 10 lbs. for approximately 640 popular musical selections lasting a total of 32 hours (15005).
3. Tape juke-box -- 20 lbs. only the player is required existing speakers can be used.
4. Television -- 30 lbs. to maintain signal from interrupted transmission (15005).
5. Large screen TV -- 30 lbs.
6. Microfilm and readers -- 2 lb. for reader and less than 1 lb. of film would provide more than adequate reading material.
7. Educational supplies -- less than 5 lb.
8. Telescope -- 5 lb.
9. Film -- 1 lb. for 100 pictures.

15.5 Alternate Methods of Meeting Mission Requirements

Some alternatives to the proposals in section 15.4 are possible. Instead of juke-box music played throughout the station, individual headsets could be used by the crew members. Paper documents could be used instead of microfilm. Reading material could also be sent up electronically. A smaller TV screen or projection system could replace the large screen TV.

In addition, active recreational activities could be pursued instead of passive activities. Equipment for fun exercise such a a trampoline should be provided. Hobby kits should be available based on the desires of the crew. Equipment for games such as cards, darts, and billiards should be available. Musical instruments matching crew talents should be onboard. Plants and animals which will be part of experimental work can also be used recreationally.

15.5.1 Discussion of Alternate Methods: Advantages and Disadvantages

The use of individual headsets for music would offer several advantages. It would allow only those people who wanted to hear the music to listen. It would allow for individual volume control. It would probably provide a better stereo reproduction of the music. The main disadvantage would be the increased cost and weight of providing individual units.

The use of paper documents for reading would be disadvantageous because of weight and required storage space. It would however overcome the eye-strain from using microfilm reading machines. Despite the difficulty of delivery to space, news of home in the form of newspapers and magazines were listed among the top ten relaxation preferences of astronauts (15007). An occasional surprise newspaper should be sent up with supplies to help keep the crew in touch with the "real world".

In addition, newspapers and magazines could be sent up electronically on a regular basis and saved for a day or month respectively. Thus an electronic storage area could be limited to a constant volume. Personal data storage areas could also be provided for additional document storage.

The advantages (involvement and satisfaction) of a large screen movie situation would warrant the use of the large screen TV instead of smaller screens. However, if the weight of a large screen TV is prohibitive, the smaller screens would already be available. A projection system would entirely eliminate the screen weight, requiring only a flat or slightly concave wall area. We anticipate the projector elements to become smaller and more efficient as the VGF time frame approaches. At some point, probably in screens over 12 inches diagonal measure, projectors will become lighter due to substantial glass weight savings over the glass required in conventional CRT´s.

Although a small amount of competition may be healthy amongst crew members, intense rivalries should be discouraged as they may well be detrimental to the mission, since they hinder cooperation and lead to suspicion. For this reason noncompetitive active activities are suggested.

One survey (15005, p. 4-15) found that potential crews would prefer active recreational activities in space even though they preferred passive activities on the ground.

"Devices which offer some entertainment as well as physical exercise would be the most desirable equipment for active recreational activities" (15005, p. 4-20). Certain exercise equipment such as exercycles will be necessary to maintain physical health and might provide minimal recreation. Other ideas such as a space trampoline would provide both exercise and fun.

Complex hobby kits are very popular aboard submarines, providing the builder with a challenge and a sense of accomplishment (15002, p. 486).

Friendly card games may provide some entertainment if played for fun and not overly competitive (15002, p. 486). Games of skill such as darts and billiards may prove desirable since one can compete not against others but against himself in order to improve his skills. Adjusting to playing these games at various gravities would be challenging in itself.

Musicians would be able to relax and perhaps entertain the others with their talents. "Should the company...be suitably talented, the rewards accruing from the creation of a space ensemble would probably be greater than from any other form of leisure activity..." (15002, p. 486).

Despite the difficulty of growing plants in space, the soviet cosmonauts gained great pleasure from planting and tending gardens (15001, p. 78). The same feeling of caring for another life would promote caring for pets as well.

15.6 Discussion of Unresolved Issues

One issue which must be considered is the amount of time that the crew will use for work. This has a great effect on the type of recreation required. Also as stated earlier, the amount of work has a direct effect on overall crew morale and the importance of the environment.

In considering the preferences of crews as a major factor in choosing the various activities, more information is needed about two factors: the correspondence between stated preferences and participation during confinement, and changes in preferences during long flights.

Since many people enjoy competitive sports, consideration must be given to the effects of competitive games on crew compatibility.

15.7 Summary

Morale, health, and productivity can all be boosted through the use of recreational activities. In choosing the activities that will be available aboard the variable gravity facility, it is very important to consider the preferences of the crew. In the end it is the individual preference of each individual which is of the most importance, since much of the benefit of recreation comes from the desire of the individual to pursue the activity.

We concluded that passive recreational activities (radio, movies, TV, books, education, and looking out windows) would be most beneficial aboard the VGF. We reached this conclusion based on crew preferences for these activities and also a desire to prevent intense competition among the crew.

Several active recreational activities are also viable alternatives. These include exercise, hobbies, musical instruments, and plant or pet care.

Issues which are yet to be resolved include the amount of crew work time, the correspondence between stated preferences and participation, and the effects of competition on crew compatibility.

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Timothy Stark

CHAPTER 16
Feces and
Urine
Handling

16.1 Definition of Topic

Feces and urine handling is an efficient method of collecting the wastes from the astronauts, storing the waste: fluid and solid, and exitting this waste from the space station.

16.2 Background Information

There have been a number of different methods of controling and handling feces and urine by a number of different of countries.

The following are examples of how the United States dealt with this problem from the earliest of our travels to our most recent.

The last insert is one example of how the Soviet Union solved their problem.

"Mercury Flights" (16010)

Astronauts wore a urine bag contained in their suits. Bags for defecation were not provided for. A low-residue diet for three days prior to launch was introduced so they would not have a bowel movement. Emergency containers were available if vomiting should occur.

"Gemini Flights" (16010)

Two types of urine collecting systems were used. One for launch which was Y-shaped and made of neoprenecoated nylon. Much like the mercury models, it fitted inside the suit. This type had two openings, one which attached to the astronauts body with a rubber sleeve and had a seperate opening for emptying into the crafts overboard dump system.

The other type was used once the spacecraft was in orbit. It was a flexible bag with a roll-on rubber sheath. It contained a double valve construction to prevent backflow of urine. The voided urine was then vented overboard.

Feces was collected in a plastic bag with a four inch circular opening. A germicidal pouch was placed in the bag, prior to use, to prevent or reduce gas bacteria. He then attached the bag to his buttocks using surgical-adhesive tape. After defecation, he removed the bag, placed the soiled toilet tissues in it, and pressed the adhesive surfaces firmly together.

Just as the mercury program, the astronauts ate low-residue foods prior to flights.

Emesis containers were available.

"Space Shuttle Flights" (16010)

The system consists of a commode, or waste collector, to handle solid wastes, and a urinal assembly to handle fluids.

This system may be used in zero gravity and in a one-g(Earth) environment with the orbiter in the horizontal position.

The urinal is used by both males and females, with the user either holding the urinal while standing, or sitting on the commode with the urinal mounted to the waste collection system. A contoured cup with a spring assembly, the urinal provides a good seal to the female crewmember's body. It's design normally precludes the need for females to wipe with tissue.

"Soviet Union Flights" (16010)

In the past, the Soviets would hermatically seal their waste products in rubber bags, which are put into a plastic container and ejected into space. (16004)

16.3 Proposed Mission Requirements

For astronauts to live comfortly and safely in the closed environment of a spacecraft, the management of metabolic or biological wastes is among the life support functions which must be carried out efficiently. (16010)

To be efficient, the system must be able to collect the waste, store it, and exit it from the station without troublesome and time consuming cleanup, odor, and embarrassment to the astronaut.

The system must be compatible for both male and female.

16.4 Proposed Method of Meeting Mission Requirements

In collecting the waste, the method will be much like the method that is presently used aboard the space shuttle.

This waste collection system may be used in zero gravity and in a one-g(Earth) environment with the orbiter in the horizontal position.

The system consists of a commode, or waste collector, to handle solid wastes, and a urinal assembly to handle fluids. The system has a set of controls that are used to configure the system for various modes of operation, namely: urine collection only, combined urine and feces collection, emesis collection, and redundant capabilities.(16010)

A study was done in a NASA KC-135 aircraft flying parabolic maneuvers. The study was aimed at defining requirements for transport airflows, and as a result, airflows were increased eight-fold for the urinal and three-fold for the commode from those used on skylab.

The urinal is used both by males and females, with the user either holding the urinal while standing, or sitting on the commode with the urinal mounted to the waste collection system. A contoured cup with a spring assembly, the urinal provides a good seal with the female crewmember's body. It's design normally precludes the need for the females to wipe with tissue.

During urination, an airflow and resulting pressure differential draw the urine into a fan separator, which separates the waste water from the environment air. The fluid/air mixture is drawn into a rotating chamber, where centrifugal force acts to push the fluid along the outer walls of the chamber and into a tube leading into the waste storage tanks. The air is drawn out of the chamber axially by a blower and returned to the cabin after being filtered to remove bacteria, dirt, and odor. (16010)

To operate the collector during defecation, the user positions self on the commode seat. The foot restraints and the seat belt were not really equal to the task of keeping someone down on the toilet. Some astronauts favored a thigh restraint, in the form of a bar that could be swung across the lap - one could be held down and have someplace to rest one's reading material. The crewmember uses the equipment like a normal toilet, including tissue wipes. The tissue is disposed of in the commode.

An airflow draws a solids/air mixture into the commode. The tines of a rotating slinger shred the feces and fling it onto the commode inner wall, where it adheres in a thin layer. The tissue does not shred, but slides up and over the rotating tines and is stored with the feces. Air flows through the collector, out through a bacteria filter, and into the fan separater, the same one used for urine collection. Slinger tines in the filter area deflect debris and keep it from occluding the filter.

The commode is used in a slightly different manner for the disposal of used emesis collection bags. A bag containing vomitus is sealed with velcro, and deposited in the commode. The user changes the mode of operation so that the slinger rotates at slower rate. The tines stay folded, and the bag has a clear passage. Air flow and the rotating slinger move it into the storage container.

Everything stored in the waste collector - feces, tissue, and fecal and emesis bags - is subjected to vacuum drying in the collector. When not in use by the crew, the inlet to the commode storage compartment is sealed and the interior of the compartment exposed to space vacuum to dry the waste stored there. The vacuum deactivates the bacteria and thus prevents odor formation. The valve opening the vacumm vent line to the commode is normally left open.

For this reason the vacuum valve must be closed and the commode must be pressurized before it is used. Commode repressurization takes approximately ten seconds. Then the gate valve at the commode inlet slides open to expose the collector for use. All valves in the commode system are interlocked to prevent operation in the wrong sequence.

On-orbit sanitation requires only that the astronauts periodically cleanse the urinal, commode seat, and other exposed areas with a sanitation agent and wipes. These wipes are disposed of in the wet trash storage compartment.

The wet trash stowage is a passive plastic-lined container in which used food bags, wet towels, wipes, tissues, soiled clothing, expended medical supplies, and personal hygiene items are disposed. It is vented to the waste collector system for odor control.

The waste water storage tanks not only receive biowaste fluids but also handle wash water and the condensate water from the airlock, portable life support system, and cabin air revitalization system.

The waste collector and the units for waste water and wet trash storage form an interrelated system for waste management on the Shuttle orbiter. Separating the storage areas and isolating levels of contamination prevent the highly contaminated wastes from spreading bacteria to everything else. This arrangement also makes it easier for spaceport ground crews to remove wastes from the shuttle.

Waste management, like many other areas of space flight, is on its way to becoming routine. (16004)

A considerably large problem with living in space is bone loss. In order detect possible bone loss on the crew, tests must be done by taking urine and feces samples a number of times throughout their stay.

After conversing with Darla Duval, who is in charge of the research being done on bone loss, we together decided to test fecal matter once every three days. At that time it will be collected in a plastic bag such as the one used on the Gemini flights. This system will save money and weigh less than if a system was used to mechanically seperate and package the fecal matter by means of the commode. The bag containing the fecal matter will then be sent to be freeze dried and tested at the department with the proper facilities to do so.

To collect urine for the bone loss tests, Miss Duval and I discussed that small amounts of urine must be collected at each sitting totaling to 50 milliliters a day. In order to collect this small amount of urine at one sitting, a pressurized tube, about the size of a test tube, will be able to attach to the urination tube of the commode by means of ballbearings. This locking devise is much like the connections that can be found on high pressure air hoses.

Between the pressurized tube and the actual connection to the urination tract, is a valve which limits the amount of urine flow into the pressurized tube.

Lines will be evenly spaced on the tube to indicate the amount needed at each sitting.

16.4.2 Weight Estimate of Proposed Method

The commode will be made of mostly plastic and aluminum with a few parts made of stainless steel.

On the average, there is two pounds of fecal matter and urine per day for every five man crew. (16002)

The estimated weight is 1640 pounds. This weight includes the commode 120lbs.; seat restraint 10lbs.; urine collection system 30lbs.; storage tanks 400lbs.; 90 days of waste for six crew members 1080lbs. The commode includes the spinning tines, the centrifugal walls and motor, and the seat.

The 1080lbs. of waste will be transported to the Shuttle on its tri-monthly visits. The Shuttle will then shuttle this waste back to Earth.

16.5.1 Alternate Methods

First Alternative:

The same type bag that is used for collecting the emesis may be used as a back up to the waste collection system for fecal collection. The bag is attached below the commode seat and expands into the commode volume. After use, the bag is released into the commode opening. The bags are made of Nomex material with a porous teflon liner, which allows air to flow through the bag and move into the storage area. (16010)

16.5.2 Second Alternative:

Taking the weight of the original method in mind, the alternatives must be light weight and compact.

If for any reason the primary method is out of commission and the secondary method has failed or is unable to work under the certain conditions, a third alternative will come into play.

Much like the Opollo systems, a urine bag will be worn as was used aboard the command module.

To collect the fecal matter, a diaper type system will be used just as the system that had been used during the extravehicular activity operations.

Both the fluid and solid wastes will be stored in the same storage tanks from the primary method.

16.6 Discussion of Unresolved Issues

The actual location of the storage tanks have yet to have been research.

The full storage tanks will be replaced with empty storage tanks that will be provided by the shuttle on its tri-monthly visits. How this is going to be done has not been researched.

Research must be done for more center of gravity calculations due to the day-by-day changes in weight of the tanks.

16.7 Summary

I conclude that this system is very possible. A majority of the task is now complete by means of an operating commode that fits the requirements that will be needed.

Doing the research brought to my mind the minor problems of every system that will be aboard the station are not minor. Any problem is a major problem knowing that lives depend on the correct solutions.

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CHAPTER 17

CREW SCHEDULING

Doug Kelley

Paula Sollom

April 28, 1987

17.1 DEFINITION OF TOPIC

A crew schedule is the daily, weekly, monthly, and possibly yearly routine that must be incorporated to include all of the following:

- work
- exercise
- recreation
- meals
- housekeeping
- sleep
- resupply of station
- change of equipment
- change of crew

This is to ensure that their order and routine is not detrimental to either the station or the physiological and psychological well-being of the crew.

17.2 BACKGROUND INFORMATION

The crew is responsible for two support elements on a space station: (17003, p.3.113)

Crew Facilities	Crew Activities
ECLSS	Onboard training
Personal hygiene	Scheduling/work integration
Waste management	Organization systems
Contamination	Inventory
Food systems	Housekeeping
Laundry	Off-duty
Clothing	(Logistics)

Vibroacoustics (Inflight maintenance)
Medical
Health maintenance/exercise
Recreation/leisure
Safe haven
(Private communications)

It is assumed that there will be a 24 hour day. At this time there is no reason to change the 24 hour clock. There will be much confusion between the ground crew calendar and the Variable-Gravity Research (V-g) Facility crew calendar if it is changed. The book "Pioneering Space," by James and Alcestis Oberg, states that from 1971-77 the Soviets shortened the day on their Salyut missions in order to keep constant radio contact with the cosmonauts during their waking hours. The Soviet space planners had done this by shortening the day half an hour to 23 1/2 hours. This thirty minute change caused cosmonauts to wake fatigued and irritable, eventually they began taking medication to fall asleep earlier every night. According to chief Soviet spacecraft engineer Konstantine Feoktistov, these "sliding days" had a negative effect on the cosmonauts' well-being (17004, p.34).

It was found by Dr. Charles Cziesler of Harvard University, however, that the body's internal clock will run slightly longer than twenty-four hours if it does not receive any external reset cues. A worker in space can adapt more easily to later hours than to earlier ones (17004,p.35). This suggests that if the day is changed in any way, it should be made longer, not shorter. Until otherwise proven more efficient, however, it is suggested that the 24 hour day be kept.

It is assumed that the week will be the same on the V-g

Facility as here on earth: work Monday through Friday; Saturday and Sunday will remain open as the weekend. This is suggested in order to remain consistent with the ground crew calendar; and also to allow for religious observances. The term "work" here stands for the actual experiments, studies, and projects that the crew members will have to accomplish. This is not to say that the crew members will have nothing to do on the weekends. They will be required to maintain communications with ground control, carry out housekeeping duties, undergo onboard training possibly, keep food systems running well, exercise, carry out waste management, plus many other duties to keep the station in good working order (They will, of course, have to monitor any ongoing experiments, though).

These assumptions have been made with the intent of changing them if necessary.

17.3 PROPOSED MISSION REQUIREMENTS

1) All crew members will have the same day(s) off.

2) The long-term crew schedule must include flexibility for religious observances and holidays.

3) A method must be found in order to achieve adherence to the long-term schedule. Also, there must be a method to determine if the schedule must be changed and how this change will be achieved?

4) A crew member will be "on call" twenty-four hours a day, by using two shifts of three crew members each.

5) A flexible schedule is needed in case of an emergency such as a breakdown of equipment or injury of one or more crew

members.

6) The daily crew schedule will have an eight hour sleep period and a nine hour work period with time for eating, personal hygiene, exercise, recreation, and housekeeping duties.

17.4 PROPOSED METHOD OF MEETING MISSION REQUIREMENTS

It is suggested that these requirements be met by using a "flex-time schedule", where the crew members have a significant voice in the workload scheduling. This flex-time schedule could come in two different forms: one which is strict, only allowing the crew members the flexibility to choose which experiments to perform during their work period; or, two, allow the crew members to make changes in the schedule of the entire day. Both of these are discussed below:

1) The Soviet crews identified the psychological need to have some options to control themselves. The Americans felt that they could do a better job if they could arrange parts of the work schedule themselves. They wanted a menu of things that needed to be done that they could select from and organize. Trying to keep to the schedule was sometimes confusing and made it difficult to conduct some experiments as carefully as they would have liked. (17001, p.4)

2) The stresses experienced in all areas of the space environment are intensified by the highly pre-arranged schedules. Americans and Soviets wanted to have some options in the day-to-day organization of the work and leisure schedules that would permit them to exercise some control over the effectiveness of their work (17001, pg.4). Such as, allow the crew members to

get up at 8:30 rather than 8:00am. The crew member will still be required to put in his nine hours at work, and then he can eat dinner at 5:30 rather than 5:00pm. But, if he does not want to eat at 5:30, when he gets off work, then he can do his household tasks. After he has finished his chores he can eat.

In either of these two cases, the mission requirements given in section 17.3 will need to be met.

It is suggested that all crew members have the same day(s) off, because, inevitably, someone will get in somebody else's way during the day if one crew member (in one capsule) is working and the other two have the day off, or vice versa. The two that have the day off may constantly get in the working crew member's way therefore causing a decrease in his production.

The long-term crew schedule must be open to holidays and other religious observances; this should include Saturdays and Sundays. Soviet space doctors found, with the Salyut-6 mission, that a two-day weekend was the most efficient rest period, which they call "active rest" (17004, p.38). To more accurately define "the schedule must be open" one must understand that certain activities will necessarily have to be done regularly such as waste management and other housekeeping activities. "The schedule must be open" pertains to the experiments and projects being conducted onboard; meaning that the crew members should have a break from that work schedule. The crew's calendar should include major holidays such as Christmas, Easter, Hanukkah, etc. National holidays (if necessary) will be decided depending on nationality of the crew (will the crew be international?).

A method must be found in order to achieve adherence to the long-term schedule. Capt. Finn Ronne stated in "Antartica, My Destiny" the need for "punctuality" as it was "best for morale that the men keep busy" (17007, p.221). If the crew members do not stick to the schedule there could be a serious reduction in productivity by the crew. The crews will be required to meet certain goals. They will receive experiments that they must provide reports on in a certain amount of time, so these experiments and project must be kept on schedule in order to avoid a backlog of projects. The crew members should keep these goals in mind. Would a crew member be responsible for keeping the crew on schedule or would ground control monitor the crew's activities to keep them on schedule? According to a paper in "R&D Productivity" M.A. Novikov stated that, for a crew of 2-3 people, they try to avoid having a commander. The Russians avoid the distinction of a commander so that the cosmonauts can "develop a spirit of cooperation" (17005, p.358). Yet, it could be detrimental to not have a commander, or would one of the crew members emerge as the natural leader? Also, if there is a change in the schedule how would this change be achieved. How would it be determined that there needs to be a change in the schedule?

Three and/or six crew members can be "on call" twenty-four hours a day. The astronauts of the first long spaceflights did not sleep well because of the maneuvers and radio communications carried out by the other crew member in the cramped quarters. Eventually the crews were scheduled to sleep at the same time and Mission Control kept watch over the spacecraft. But, the

Shuttle/Spacelab crews worked on shifts. This arrangement worked well because one crew could work in the Spacelab, in the shuttle's cargo bay, while the other crew slept in the cabin undisturbed by the working crew (17004, p.36). Both of these ideas play a role in the V-g Facility because it has two capsules. For example, all three crew members of a capsule can be asleep at the same time (which is necessary since they are in the limited space of the capsule) while the three crew members in the other capsule are awake. If any problems arise a crew member of the other capsule can be awakened to take care of the problems.

By dividing the crew of six into two shifts; shift one would be in capsule A, and shift two would be in capsule B. When shift one is waking up, shift two will have already been awake for twelve hours. This is represented in the figure below; it shows when each shift would be awake or asleep during a two day period.

```
   (The hour of the day is read top to bottom: i.e. 2 = 24.)
                                                    4

hour of               1111111 11122222                   1111111 11122222
the day     12345678 90123456 78901234 12345678 90123456 78901234
---------   -----------------------------------------------------
capsule A   WWWWWWWW WWWWssss ssssWWWW WWWWWWWW WWWWssss ssssWWWW
capsule B   ssssssss WWWWWWWW WWWWWWWW ssssssss WWWWWWWW WWWWWWWW

    W = hours awake
    s = hours asleep
```

With this arrangement shift one will wake up at 9pm and will go to bed at noon. Shift two will wake up at 9am and will be in bed by midnight. However, a flexible schedule will be needed in case of a breakdown of equipment or some other emergency (17006, p.6).

This will allow for a safe, efficient change of schedule.

The daily crew schedule will have an eight hour sleep period, as shown in the table above, plus a nine hour work period and time for eating, personal hygiene, a handover period, housekeeping, and recreation.

The work period will be the time that crew members spend with experiments and projects. Their exercise time may also come during the work period since the physiological study of the body will most certainly be an ongoing study onboard the V-g Facility. But, the crew may not need a full two hours of exercise which has been suggested by some sources (1700, p.1.59). This is due to the fact that the crew will not be in a zero gravity environment and therefore may not need as much exercise. The crew onboard the V-g Facility must, however, vary their exercise time in order to find out how much exercise is needed at different gravity levels. This will, of course, allow them to determine how much exercise time is needed to keep the human body physiologically fit at specified gravity levels.

The crew should have one hour in the morning and in the afternoon for breakfast and personal hygiene (shaving, brushing teeth, etc.), and lunch and personal time. They will have 1 1/2 hours for dinner and personal time. After breakfast and dinner there will be a 30 minute period allotted for handover procedures between the two capsules, as one shift finishes work and the other shift prepares for work.

All crew members must perform housekeeping duties and should rotate these duties between themselves. These housekeeping duties, especially cleaning and disinfecting, should be done regularly. First the areas to be cleaned must be identified and then grouped according to priority. The housekeeping should be done after the last handover of the day. The Skylab crews had 4 1/2 man-hours/day of housekeeping (17008, p.4,5), which, for a crew of three breaks down to 1 1/2 hours per crew member. A regular schedule, probably weekly, should be created to avoid additional problems. If the crew members rotate the housekeeping tasks, the job won't become too tedious. (17002, pg.1.66)

A pre-sleep period of at least one hour of mentally nondemanding activity is needed to relax the crew members. It was found that this one hour of relaxation was important for the crew members on Skylab. This period of relaxation allowed the crew to relax from the day's work and to fall asleep easily at night. (17002, pg.1.58)

This table shows a crew schedule that incorporates these requirements to make up a daily schedule. Shift 1 would be in capsule A and shift 2 would be in capsule B; the twenty-four hours of the day are represented by the column in the center.

CAPSULE A	HOUR	CAPSULE B
Sleep	1	Workday in Progress
"	2	"
"	3	"
"	3:30	Eat and Personal Time
"	4:30	Resume Workday
"	5	"
"	6	"
"	7	"
"	8	"
"	8:30	Eat and Personal Time
Eat and Personal Hygiene	9	"
Handover operations	10	Handover Operations
Begin Workday	10:30	Housekeeping
"	11	and
"	12	Personal Time
"	13	Sleep
"	14	"
"	15	"
Eat and Personal Time	15:30	"
Resume Workday	16:30	"
"	17	"
"	18	"
"	19	"
"	20	"
Eat and Personal Time	20:30	"
"	21	Eat and Personal Hygiene
Handover Operations	22	Handover Operations
Housekeeping	22:30	Begin Workday
and	23	"
Personal Time	24	"

17.4.1 DISCUSSION OF PROPOSED METHOD

The disadvantage to the flex-time schedule is that the crew can possibly fall behind their work load if the schedule is too lenient. But, this daily schedule has enough discipline to keep the crew on schedule, and can be a very productive schedule to work with. If the crew members desire, they can flex this schedule 30 minutes or so (but not much more), as long as they keep certain restrictions in mind. Such as the handover procedures which have to be done at a certain time, also they must remember to keep to their nine-hour workday, etc.

17.4.2 WEIGHT ESTIMATE OF PROPOSED METHOD

At this point there is little or no weight requirement.

17.5 ALTERNATE METHODS OF MEETING MISSION REQUIREMENTS

17.5.1

There are other crew schedules that can meet these requirements. One way is to use a schedule with shifts; not the shift idea as mentioned in section 17.4 with each capsule making up a shift of its own. But, rather, the three crew members of a capsule would have shifts. This has been shown to be ineffective in small groups, but it is useful in the on-site monitoring of experiments that may not be possible from ground control.

17.5.2

The rigid work schedule, were all the activities are planned out by ground control, is useful only for short duration spaceflights and will be totally ineffective for the long duration of the V-g Facility mission.

17.6 DISCUSSION OF UNRESOLVED ISSUES

How much exercise is needed?

Would it be beneficial to rotate crew members between the capsules, mixing the crews together every-so-often?

How will the holidays be handled? Will they be the same length as government holidays?

Will the crew members be able to accumulate "vacation time"?

If a crew member did get a vacation would he be responsible for any housekeeping duties?

These are a few topics that still need to be looked at.

17.7 SUMMARY

Judging from this preliminary study, using shifts does not seem to be an effective way of planning a crew schedule for crews that will be on an extended mission, except for having one shift in one capsule and another shift in the other capsule as suggested in this report. The crew could, however, use shifts for a short time period, for instance, they may do an experiment that requires close monitoring continuously for a week. For such work, shifts could be very handy.

This study indicates that a rigid schedule would not be productive, either. The crew members would not tolerate this set-up for very long. This schedule could only be used for a short period such as the resupply of the station or during extravehicular activity.

A flex-time schedule, at this time, seems to be the most productive work schedule for the V-g Research Facility, as the crew will be in the station for up to three years and they will need a schedule that can offer variability. It is suggested, however, that the crews not be allowed to flex the schedule too much as the leniency could allow the crew members to become to lazy over such a long period of time.

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CHAPTER 18: CREW SELECTION
by Nanci Pretzer
4/27/87

18.1 Definition:

Crew selection is the process of selecting candidates to determine the best possible effective group of compatible persons through the use and combination of physiological, psychological and sociological tests, and the educational and character background of the candidates in the incorporation of the mission goals.

18.2 Background Information:

- It will be assumed that knowledge from previous and ongoing testing (such tests being from the fields of intended study) will help in determining which candidates are suitably compatible as crew members.

- The selection process used to be (primarily) interested in psychometric testing ("measuring of the mental processes" (18008, p. 1454)), psychiatric evaluations, skill levels and general physical fitness. Such procedures were used in initial weeding out of candidates in the astronaut program. (18006, p. 28)

- Early psychiatric and psychological evaluations focussed on personality and emotional factors, looking to candidates for a range of high-priority and high hazard assignments. Also, in the selection process, was a concentrated emphasis on `ego strength' (personality integration). Maintaining that coping (the way a person functioned) was just as important as personality/ego strength (how well a person functioned). (18012, p. 19-21)

- Earlier Antarctic missions were largely based on peer evaluations by the potential recruits (they knew what was expected of them and of the mission).
  Similar selection (for small crews) processes were used in recruiting Sealab personnel and in Astronaut selection. This process suggests that refined testing was not needed, yet, not practical for large numbered crews. (18006, p. 40)

18.3 Proposed Mission Requirements:

Crew members will be selected from extensive physiological testing, psychological testing, sociological testing, educational background, and character requirements for the specific mission goals.

18.4 Proposed Method of Meeting Mission Requirements:

Physiological selection process will consist of a preliminary screening, a in-depth medical history evaluation and a hands-on evaluation.

Psychological selection process will consist of a preliminary personality test (ie: MMPI) and qualities of interpersonal-relationships. Candidate selection will be based on a working compatibility in a normal psychological environment. And, show a friendly outlook throughout the testing, training and mission.
Emotional stability will be determined through psycho-physiological ("physiology of the mental organs" (18008, p. 1454)) mechanisms.

Sociological selection will include compatibility testing, androgyny in role relationships (including the ability to restructure role stereotypes), crew interaction and communicability.

Educational selection consists of the crew's specialty knowledge, adaptability to change in situations and ability to learn with a high degree of mental dexterity.

Character requirements take into account the candidate's high degree of intellect, inclination for research work, ability to restructure stereotypes, psychological adaptation to the enclosed environment, intuition, flexibility, good memory, sharp wit, ability to organize activity when information is uncertain and temperament.

18.4.1 Discussion of Proposed Methods:

18.4.1.1 Physiological Selection

- Preliminary screening includes a basic physical consisting of various medical examinations ("neurology ("study of diseases of the nervous system" (18007, p. 248)), ophthalmology, ear, nose and throat examinations, endocrinology ("science of the

endocrine glands" (18007, p. 132)), etc...") as determined by the medical specialists overseeing the mission.
These tests are being done by the Soviets for the stated reasons. (18001, p. IV 44)
Included in the preliminary screening would be the rejection of persons engaged in addictions (alcoholic, drug, etc...). The screening out of smokers or tobacco chewers will have to be looked at from the selection of other crew members and safety of the crew within the station. Another area to look at is the usage of prescription drugs for medical reasons. Such screening will have to be determined by group acceptance or rejection, physiological reaction to zero gravity and/or partial gravity, equipment livelihood for the stations environmental well being, and such habits mixed with life sustaining gases that are essential to the crews survival. The advantage of a preliminary screening is to weed out the physically unfit candidates, and save time and money through fewer numbers of candidates going through testing and training.

- An in-depth medical history evaluation is used by the Soviets, to find hereditary disorders and recurring pathological conditions ("regarding the changes in the tissues resulting from disease, and/or morbid, abnormal" (18007, p. 269)). (18001, p. IV 44)
  Advantages are the further weeding out of unsuitable candidates and cost effectiveness, as stated above.

- A hands-on evaluation is also conducted by the Soviets. With the use of current technological processes, an evaluation of tests in the following areas will be done as the final determination step before the extensive training and testing begins.
    "- Roentgenography - X-ray photography. (18008, p. 1570)
    - Endoscopy - "inspection of the interiors of hollow organs." (18007, p. 133)
    - Eletrocardiography - "recording of sound waves from the heart." (18007, p. 129)
    - Laboratory tests on blood
  -- hematological evaluation - "study of the blood and its diseases." (18008, p. 845)
    - Blood chemistry
    - Neurological evaluation - "study of diseases of the nervous system." (18008, p. 248)
      -- motor coordination
      -- sensory and reflex functions of the nervous system
      -- skull roentgenography
      -- electroencephalography - EEG - recording of electrical signals in the brain." (18007, p. 130)
(18001, p. IV 44)

When these tests for the separation of candidates is completed, a final evaluation of physical responses will be done before the actual mission training begins. The noise stress test (used by the Soviets) will determine the negative effect on the auditor ("sense of hearing" (18007, p. 50)) analyzer, vegetative nervous system, work capacity and sleep. (18001, p. IV 45)

The high medical standards, used in the pasted, associated with crew selection, lowered the number of candidates who were professionally qualified.

Todays standards have been modified by more experience generated by past spaceflights. But, such standards are still limited to those without any health problems, patho-physiological conditions or possible borderline findings.

The age requirement for candidates has been lengthened from 35 to 39 years of age.

Although there have been modifications concerning the evaluation process of the candidates health, significant attention is given to blood pressure. Through such attention, a evaluation of this particular part of the cardiovascular system, may prove to find disease.

Within the scope of blood pressure is hypertension. It has been recognized that hypertension is a leading health problem, whether systolic or diastolic. Hypertension is, by the United Nations World Health Organization's definition, "-systolic blood pressure at rest exceeding 160 mm Hg with a diastolic blood pressure at rest exceeding 95 mm Hg." For the Spacelab missions, NASA, in 1977, set the standards for blood pressure at 160 mm Hg and 100 mm Hg for Payload Scientists, and for Mission Specialists at 140 mm Hg and 90 mm Hg.

For those candidates of mature age, emphasis has been given to the correlation of age with blood pressure, rather than the absolute blood pressure by itself.

With a more liberal approach to the selection process, the availability of motivated and professionally qualified candidates has greatly widened the gap of needed personnel for forth coming spaceflights.

It must be remembered that individually modified blood pressure standards for those persons, who will only be used for one or several flights, will not be, readily, used for the professional astronauts, who will be in space for long periods of time.

Such a selection process for candidates of a variable gravity facility may need to be modified by taking into account the particular professional needs, operational differences and demands. (18011)

It may appear that the physiological testing may waste time and money, but in the long run of the overall mission, they will prove to be advantageous for such a mission's success. By the filtering out of unsuitable candidates right away, less money and more time can be spent on training.

18.4.1.2 Psychological Selection

- The emphasis in selecting candidates will be done by looking for positive psychological characteristics instead of looking

for potential or actual psychological problems. (Select "in" not "out", which has traditionally been done.)
The main areas in psychological research for selection are, psychological characteristics of the candidate and, integration with, the space task environment.
(18002, p. 101-2) (18009. p. 80) (18012, p. 32)

- Any psychological illness would be grounds for rejection. (18001, p. IV 48)
- Tests to establish the candidates personality traits are necessary. (18001, p. IV 49)
  Although the MMPI test is a good indicator of personalities, it does not show a good measure of dynamic adaptive ability. (18006, p. 31)

- The psychological criteria, used by the Soviets, are looking for:
  " - low anxiety
    - emotionally balanced
    - high level intellectual and perceptive abilities
    - high resistance to long standing work
    - good attention separability and changeability
    - memory
    - capacity to control one's own reactions"
  (18001, p. IV 48)

- Living in the Antarctic and in space is similar because both are different from any other type of living environment in respect to uniqueness. Both are potentially dangerous. The crew may have to cope with emergencies, shifting from everyday monotony, to high levels of physical and psychological alertness. The high stress in emergency situations would "require an individual with psychological strength, an ability to learn quickly under unexpected conditions, tolerance for loneliness and anxiety, and an excellently functioning central nervous system". This type of person would be one who is adaptively competent ("the ability to cope with immediate changes in the environment and to adjust to long-term changes while maintaining effective performance and continuing psychological growth"). Testing for measuring competence would come from stress testing, peer evaluation (best method), the individual's developmental history, and "future-self attitudes".
  (18006, p. 25-26)

- Special tests have been developed to determine psychological compatibility. For example, the Mutual Talking Test, used by the Soviets, tries to simulate a type of mutually-dependent activity. When the partners begin helping one another, their pulse rates combine to some extent. The higher the pulse synchronization, the greater the compatibility. Through this test, the Soviets have noticed that opposites can be compatible: introverts paired with extroverts. To make compatibility work, there must be a mutual understanding of intellectual and emotional levels between the group members. (18001, p. IV 53)

Coordination of extroversion/introversion within a crew needs to be looked at for selection purposes as well. It has been found that in some instances, extroverts do not function well when in a socially isolated environment, nor do introverted individuals, function favorably, in isolation. A mixture of introverts/extroverts may be needed to make an effective, socially interactive group.

There are unanswered questions to this topic, as well as intervening dimensions that need to be answered before such selection methods are used. But such a method of selection should not be overlooked. (18009, p. 79-80)

The Soviets use compatibility to be shown by:

"- attitude toward one another
- intellectual ability
- likes and dislikes
- tact
- tolerance
- sense of duty
- willingness to cooperate
- conformability, in order to accomplish the mission" (18001, p. IV 53)

An advantage to compatibility is the knowledge the group has at an early stage of training. (Such tests should be done after physiological and mental testing has taken place.)

- Psycho-emotional stability will be determined by solitary testing and experiments to clarify psychophysiological mechanisms and prevention of unfavorable psychological conditions ("work and rest regimes, goal oriented activities, pharmacological treatment"). Without this testing, it would be impossible to insure compatibility in a long-term flight. Such results would show compatibility. However, it will not reveal how the crew will react emotionally in a emergency situation.
  Such testing is used by the Soviets. (18001, p. IV 50)

- An area which needs to be looked at is motivation. The most highly desired combination of motivational factors in the selection process is the high Work/ high Mastery/ low Competitiveness constellation outcome. The three factors were found with the use of the Work and Family Orientation Questionnaire. Work orientation looks for a positive adaptiveness to work as a rewarding experience. While, a kind of intrapersonal, competitiveness would be most rewarding in the factor of Mastery. Finally, Competitiveness looks for the winning in interpersonal situations and bettering others' performances. Disruption of the social and work environment can be caused by a negative aspect of competitiveness, which would result in a high score in that area.

With emphasis on isolated environments, such factors would be useful in the selection process dealing with performance and adjustment of the crew.
(18005, p. 12-14)

- The individual's reaction to the environment can be analyzed (cost-reward matrix: both performance and adjustment) to determine how one's perceptions are affected by the environment. When the rewards (sum of personal satisfaction or working towards future benefits) are perceived, by the individual, to beat the costs (disagreeable features of the environment and other negatives concomitant in unforeseen situations), the individual will likely be up in spirits and up in performance. (18005, p. 3-4)

- Tests should reflect the values of quality in interrelationships.
  A disadvantage to this type of testing is in the use of tests on a short-term basis.

18.4.1.3 Sociological Selection

- This selection process is similar to the process used in psychological selection area, with the emphasis on group interaction.
  Effects of confinement, perceptual and social isolation need to be examined for adequate conformation of stability.
  (18012, p. 28)
  In past selection processes, crew members were selected by choosing outstanding individuals (astronauts have been generally highly independent, stable persons). To select an effective crew, selection should be centered on a group of individuals as a group. Highly outstanding individuals may not be compatible within such a group. Individuals who are socially oriented with skills of interpersonal congruity, will be advantageous to the crew and the mission as a whole. In a long duration situation of isolation, social interaction is more important to the mission's success. (18009, p. 79)
  There must be an awareness of the social and physical surroundings of the crew's psychological and physiological functioning with dependency on the environment.(18012, p. 28)

- It will be more beneficial to select an androgynous crew, and that this crew have the ability to restructure role stereotypes. The advantage of this means of selection is for a more emotionally stable and compatible crew. (18003, p. 173)
  Hermaphroditism within a selected crew is very important in the selection process because of the concern that the two sexes, living in a confined environment for a long duration, would effect the performance of such a crew and the personal performance of the individual.
  Selection will have to centralize on the concept of psychological androgyny. This process will find people who score high in both masculinity (attributes: instrumental, goal-

seeking oriented) and femininity (characteristics: psychological expressivity, sensitivity to the feelings and needs of others). There are many reasons for this importance, all of which will help in the crew's interaction and compatibility for the long duration perceived for the flight.
Both males and females with an androgynous advantage are found to have a self-concept, which is positive, and are able to appear effective in an interpersonal way. With the mix of masculine and feminine traits, both sexes should be easily adaptable to a change of personal needs, desires and openness, within the social structure of the living arrangement.
(18005, p. 10-11, 16)
With the consideration of situational and role demands, the psychologically androgynous person (with regards to the performance of sex-linked roles) "is capable of both effective goal-oriented behavior and effective interpersonal relationships." Such demands are weak and involved, although one scores high in masculinity or femininity, does not necessarily mean their career choice will reflect such a score. It depends on how one chooses to vent their androgyny.
(18005, p. 11)
With a combination of these attributes, a selection of such a person would be highly desirable for space.
There is no conclusive evidence that a sexually-mixed crew's performance is altered by such a mixture, on the contrary, "sex is not a relevant dimension". (Couples would not solve the intensity of the situation.) It is important to state that strong prejudice about roles of the sexes and/or abilities, by the crew members, could be reflected in their performance.
With a long-duration mission in a restricted environment, a heterogeneous crew would have to expect sexual and other interpersonal conflicts a probable consequence to such situations. Environmental changes will have to be met to accommodate individual needs and desires within such a social structure. (18005, p. 17)

- There is a definite need to have excellent crew interaction and communicability for a successful mission through unified mutual sympathy, friendship and common view points.
  It is possible to experience chaos with a breakdown in the flow of communication. To keep such a breakdown from happening, ongoing conversation links must be kept open (crew reactions to and of reality and identity) for the greatest achievement of social interaction. (18002, p. 102)

18.4.1.4 Educational Selection

Specialty knowledge consists of the needed abilities for the mission goals to be accomplished.
Each candidate must show a high degree of mental dexterity. This means that he/she has the ability to cross train. Knowing something about each crew members' specialty area

helps in emergency situations, relieves boredom and creates a common bond among the crew.
It is possible to risk losing a very knowledgeable specialist due to lack of compatibility. (18000)

18.4.1.5 Character Requirements
This is ascertained through the evaluation of the tests and training results. A good character in crew members results in a successful mission outcome. (18000)

18.4.1.6 Final Testing
- This stage involves the isolation of possible mission groups. A 30-90 day simulation will be used to determine how the groups will probably react in a confined area, such as the variable gravity facility. This type of simulation would help in identifying areas of potential difficulty and to develop techniques in programing to avoid such problems. This will help in reducing risks as much as possible. The longer the simulation is run, the more that will be learned. However, the expense will be greater for the extended tests.
  Isolation testing is done by both the Soviets and the United States, as well as other nations for various reasons.
  (18001, pp. IV 33-34)(18004, pp. 11-15+)
- The intensity of intimate training and preparation of the crew for a long duration before the mission is enacted, will be most effective for prevention of divisional conflicts between the members.
  IE: Early teams of astronauts and including Skylab.
  (18002, p. 101-2)

18.4.2 Weight Estimates of Proposed Methods:

N/A

18.5 Alternate Methods:

18.5.1 Any experiments for the various tests should be evaluated. A board of experts would be best for an evaluatation.
Using a board of experts to evaluate tests would help in receiving a wide range of opinions and brainstorming for establishing the best tests to be used.
This type of evaluation would be time consuming, but could be needed to achieve rational decisions on problematic situations which could arise. (Such a board would be independent of scrurtinization by those involved in the selection process, institutions and other decsion making entides.)

18.5.2 An alternative to the selection process is found in psychological training, used by the Soviets, in adding safety to space flight. This training tries to take into account rational and fully accountable psychological personality features of the individual cosmonaut's. Such situational conditions are wanting cosmonauts' "ability to behave actively under emotional stress", measured for the importance to the efficiency of the flight. The measurements of the psychological training are "real-life" situations, used to cause "real-life" reactions. The methods employed to cause such reactions are flying and parachuting.

Parachute training is used to measure emotional background characteristics with an incorporation of the "task purpose". Flying (emergency landings in different geographical and climatic environments) is used to simulate the emergency situations that may be encountered in space flight. This helps in the ability of the cosmonaut to handle stress by previously performed similarities in training.

Basically, such training prepares the crew psychologically for potential hazards, and gives them the practical knowledge needed for survival. (18010, p. 1-4)

Such a method used to measure psychological conditions would be advantageous to the mission's success because it measures reactions under "real- Life" situations.

A disadvantage may be one of expense, both monetarily and livelihood.

18.5.3 Isolation testing could possibly be done to find out if monitoring those who are in isolation verses not monitoring, and measuring the results when done, as to which is better or worse. And, if all male/all female/mixed crews would be more beneficial.

The isolation testing, which is suggested, would be useful in measuring the differences before and after such experiments. With different mixture of sexes in isolated groups, it would need to be found which group worked, compatibly, the best. Disadvantages would come from the time and expense that would have to be used for such testing.

18.6 Discussion of Unresolved Issues:

- Competence - developmental history, as related to neuropsychological functioning. And measurements of functional lateral differentiation. (18006)

- Stress - adaptation in association with dissociation susceptibility differences, from a psychological aspect, still needs to be examined. (18012, p. 30)

- Handicapped candidates - it would have to depend if the person adequately passes the selection process, and works well within a group of unprejudiced group members.

- Religion and race - (equal opportunity employment) - it would have to depend on the person and the other group member's prejudices.

18.6.1 Discussion of Information Not Yet Formulated:

- Educational information - the process of how one is selected by a varied educational background, and how such criteria would be integrated into a group, has not been forth coming.

- Character requirements - there has been a slight indication of progress from information that has already been incorporated within this formulation, but none has been specific. Additional information is needed.

- Information on crew selection procedures - additional sources, other than that which is in the scope of selection processes for space, can be applicable for further enlightenment. Such a source would be the procedures used in the airline industry for selection, testing and training of it's professional pilot crews.

18.7 Summary:

The selection of a crew for a long-duration flight must take into consideration the integration of the individual's well-being and the individual interaction of the group to that individual. Many factors have to be looked at and, possibly, modified (to a point) to give those persons of outstanding pleasantries, to the tasks involved, and workability within a group, the cooperation which is needed for the mission's outcome.
An issue with importance to this mission is that of money. Time can be lengthened, but money, being allocated, can not be (unless such selection processes, testing and training are backed by inde- pendent entities) thrown about. With such pressures as money, selection must begin with educational qualifications and physical (preliminary) qulifications. After which more time and expenses can be focused on the testing/training (to a lesser extent) that is essential to the outcome of the mission. Such focussing would also involve (primarily) the sociological testing, which will be used on forming effective, workable groups.
The more the group is informed of what is expected of them and by them, workability, of an acceptable outcome, will be achieved.
Within the frame work of selection, the goal of the missions success must be remembered and reminded throughout the process. If it is lost, a failure could be found as the ultimate outcome.

18.8 References:

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Chapter 19

Psychological Effects on Crew Members for Long Duration Space Missions

By: Gary Thompson

I have five sources to serve as the main basis for the information presented here. They are:

Pioneering Space (19001)
Mission to Mars (19002)
Space World (19003)
Soviet Space Station as Analog (19004)
View of Human Problems to be Addressed for Long Duration Space Flights (19005)

NASA needs to take a look at these issues in order to make the necessary decisions. Decisions that will determine weather a long term mission will be a success or failure.

Many of these issues are as follows:

Oberg says the Mercury astronauts submitted to twenty-three psychological tests prior to space flight selection. At that time, the space program wanted intelligent (especially in mathematical and spatial functions), (19001 p 138) reliable, consistent, deliberate, self-confident, and motivated men who were calm in ~~and~~ emergency.

In later years, when the manned space program's aims changed, so to did the image of the ideal astronaut. Intelligence, motivation, and level-headedness in an emergency were still prime requisites. But now, the astronaut personnel office preferred cooperative, socially compatible, well- rounded human beings, with the emphasis on cooperation.

Psychological tests had been dropped from screening procedures in 1977 because they were deemed ineffective gauges of human personality, judging from the later history of some of the astronauts who had "passed." However, current American would-be spacefarers still have to go through a test for claustrophobia, a psychiatric interview, and some stomach wrenching airplane aerobatics before they can be picked to ride aboard the shuttle.

Neither Russian nor American spaceflight commanders are allowed to name their crew, although a commander can put in a good word for someone. Crews are named by flight-operations director, based on seniority, specialization, and intuition. But in selecting people for long-duration flight, the Russians put their cosmonauts through more stringent and sophisticated psychological screening. All American space-shuttle flights (and most Soviet orbital visits, too) last only about a week, and one can put up with just about anybody for that amount of time. But some Soviet orbital expeditions last half a year or more. (1901 p. 139) "O'Henry, the American writer, wrote in one of his stories that if you want to encourage the craft of murder, all you have to do is lock up two men for two months in an 18 x 35 foot room." The interior of the Salyut is only about six by eight by thirty feet. The consequences of incompatibility and conflict among crew members could be extreme.

A laboratory head at the Institute of Biomedical Problems and an important figure in Soviet space psychology, "In a cooperative activity [the hemostat], there are frequent situations where the subjects counteract each other in the 'struggle for the ultimate way' with pronounced behavioral reactions--fidgeting, remarks against the partners, disapproving looks in each other's directions, and so on. The activity loses its cooperative nature and has a distinctly competitive character." This, I think, should be studied more in depth by NASA. (19001 p.p. 140-139)

The Russians carefully noted that reaction time varied greatly among tested pairs. How a cosmonaut tuned out interference from outside and from his partner, and what his body posture expressed were also of interest. Factors that seemed to influence compatibility included intellectual ability, skill, a positive attitude toward the activity and each other, mutual empathy, learning ability, adequate distribution of work and responsibility, and uniformity of physical responses.

Next the cosmonauts are locked in airtight chambers--one representing the space craft, the other the space station--for periods of ten days to three weeks, simulating a real spaceflight.

On~~t~~ the first day, test subjects made it to sit in their spacesuits, simulating launch problems until their knees go numb. After three days of intensive work, their pulse rates drop, they become fatigued and stressed. By the twelfth day, noise levels, physical discomfort, and fatigue have piled up.

I Don't think this is necessary, subjecting trainees to more physical discomfort than is required has no significant value. (19001 p. 141)

Two men who are naturally competitive, are terrible risk for a long-term space voyage.

After extensive research along these lines, the Russians found that crews tended to break down into one of three characteristic types: "congruent," "complementary," and "competitive."

A congruent spaceflight team consists of individuals who are similar in personality and can function interchangeably at the various tasks.

In complementary teams the personalities of the teammates are different. "People with 100 percent different personality traits proved to be compatible. An open-hearted, easy-going and sociable person might be at ease with a reserved, taciturn and private person. It is important that they coordinate with each other emotionally and intellectually."

Compatibility even went as far as the heartbeat. "The pulse of partners helping each other synchronizes. Whether such things as heart rates and menstrual cycles can be indicators of psychological compatibility has yet to be proven.

The closer the pulse rate, the better the cooperation between the cosmonauts.

Congruent groups, consisting of people of similar personalities, performed inconsistently in problem-solving situations. "The presence of rigid structures in congruent groups who strictly follow the leader-follower concept negatively affects problem solving."

People who are too similar can get on one another's nerves, "it is advisable to form crews in such a way that the merits of each member are complemented while the defects are smoothed over." (19001 p.p. 142-143)

The Russians found that although such complementary teams tended to need longer training. The US effort should consider this to be beneficial in crew selection. A little additional time will ultimately proved their worth. "Support group unity incases of monotony." In essence, such teams were more flexible in their problem-solving tactics, and tended to make up for one another's deficiencies. (19001 p. 144)

Russian spacefarers repeatedly counsel each other informally on psychological matters, an~~d~~ impossible dream for American spacefarers with their traditional hostility to all things psychological.

Prior to flight, some cosmonauts made pacts to work together to solve interpersonal problems. "There should be complete frankness." (19001 p. 145)

Although some in Russia swear by the psychological compatibility testing and the heart synchronization measurements, not all do. Quite often, external conditions or problems dictate that crews be changed around.

"Good relations are dependent not only on psychological compatibility, but also on the individual qualities of man. Remarkable results come from patience and restraint. Unplanned situations can always arise. Any heating-up of the situation will also decrease your performance and your feeling of well-being. (19001 p. 146)

How much space does a person need for privacy?

Unfortunately, there's no easy answer. I think privacy is as much a matter of culture, sex, duration of stay, familiarity between crewmates, and personal idiosyncracy as it is of volume or space. "Privacy is a means by which people can regulate their relationships with other people."

Women are more cooperative than men under crowed conditions, but not for long periods of time.

Crowded cultures, like the Eskimos, who must live at close quarters in a hostile environment for months at a time, crate a series of social masks behind which they hide. All cultures develop rules of etiquette governing social distance and personal space. (19001 p. 193)

Crowding is a very individual perception. What appears crowded to one person may seem cozy to another.

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People often personalize small spaces with mementos and photos, like naval officers do their lockers, as a means of preserving privacy. In space, many of these methods have already been resorted to. Cosmonauts hung pictures of their families and kept souvenirs from their children.

Spacecraft designs in both space programs have considered creating true physical private spaces for space travelers. (19001 p. 194)

"In space crewmembers must depend on each other for their day to day survival. Individuals in a threatening situation prefer to be in the company of others, not only for the acceptance, verification, and comforts but also for safety. As long as a high level of interdependence exists.

(19001 p. 195)

Looking out the window is a restful pastime and a means of mental escape from the environment. There should be adequate viewing ports and interior spaces should be shifted around as we learn more about how groups relate to the environment during long space flights.

Mission to Mars

"On submarine crews we can study patterns of depression and activities to dispel depression". In particular, we can observe communications breakdowns and displaced hostility--which in space would be directed against the people in Mission Control." The polaris submariner is a highly screened individual also placed in a chronically stressful and frustrating environment.

It is may belief that a polaris submarine represents an ideal laboratory in which to study the dynamics of group adjustment to unusual environments. Psychological stress can have physical manifestations which fellow crewmembers and Mission Control experts might be able to notice and diagnose: drowsiness, disorganization, misinterpretation, hostility, daydreaming and absentmindedness. Soviet psychologists monitor the stress level of cosmonauts by doing a "voice stress analysis" on the harmonics of the crewman's voices, a technique, applicable on the mars mission.

They constantly plan ways to introduce novelty into the crew's routines, via "surprise packages" sent up from earth inside supply ships, plus conversations both with family, with friends, and with total strangers who have interesting professions or backgrounds.

The soviets actively teach their cosmonauts how to cope with expected psychological stresses of space missions. Such an

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approach is the way American space doctors will have to learn to function for the Mars mission. (19002 p.p. 76-77)

"There should be an odd number of crewmembers, so as to avoid deadlocks. Experience has shown that even numbers of people under stress tend more often to split into two equal and opposing camps, unable to reach a democratic solution to urgent mission decisions."

Maturity and an absence of separation stresses involved with minor dependent children might call for older personnel.

These desired characteristics might tend to force the selection of people between the ages of forty-five and fifty-five years old. A crew with an average age of about fifty would probably be the most capable possible selection.

(19002 p. 79)

19-9

Making Space a Nice Place to Live

Anything that relieves the tedium, the boredom, the barrenness of life in deep space is the interest of long duration space missions (19003 p. 9).

Crew station design is now involved in space station planning, defines habitability as the individual's perception and attitude towards the quality of life in a given environment. Habitability is not a simple matter of color, space, privacy, communications, or any one single factor. It is, rather, a presence of all these things and more. Further, the success or failure of entire missions may depend upon that matrix of factors. In my estimation individual crew comfort requirements should be a major factor in design. Variety is an unsurprising key ingredient for the physical components of habitability. Several astronauts aboard America's first space station, Skylab, complained about the facility's bland tan-brown interior color scheme. Music was an astronaut's relief in the earth-circling laboratory. Physiological and psychological factors, however, are even more important in long duration space missions.

Deconditioning and Local Vertical

Space Adaption Syndrome is the space agency' catch-all phrase. Shuttle spacesuits have extra room allowed, designed to anticipate the human body's lengthening once in orbit. Other human issues are those of personal hygiene, privacy,

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recreation, work scheduling, communication and the usual one of "local vertical."

It's harder to shower in space--lathering up is easy, but removing lather can be a tedious and time-consuming task. In addition, there's the matter of changing your clothing. What is optimum? Astronauts expressed a universal desire for a clean change of undergarments each day. "Each of these factors is minor, but they mean a lot."

Skylab, with its mix of large and small areas, offered room both for gymnastic recreation and that precious commodity privacy. (19003 p. 10)

Leisure time to read, to think, or watch the earth go by, is far more important than had been realized.

Communications with earth, and particularly with family, help relieve the isolation of space travel. It is undoubtedly vital in reducing interpersonal conflict. "In space, your actions impact the lives of others. You have to learn to cope with that, to subvert your freedoms for the good of the group."

Although there is no natural "up" or "down" within a space vehicle's room as a wall. All Skylab astronauts consistently experienced disorientation in the lab's docking adapter, a cylindrical area of the station which had wrap-around equipment and containers instead of vertical.

"You tend to orient yourself when you're in a room ~~event~~

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though you're in zero-gravity, and when you orient yourself you should find everything is the same."

Habitability is a mixture of physical, psychological, medical and sociological components--all aspects of the human factor. The pertinent questions about habitability for the proposed space station are: will engineers incorporate it into their designs and will congress realize its priority and fund it accordingly? Engineers should put a little more imagination into a design, other than just efficiency. A little extra thought in this regard can go a long way. (19003 p. 11)

SOVIET SPACE STATION ANALOG

I Environment

Decor

Color and Music

The Soviet Union has experimented with combining musical works and color images. They recommend that:

-Music be selected first
-The appropriate slides or films that complement the music be added. (Something similar to videos with music using relaxing images.)

Ground-based studies indicate that these color-music films improve operator activity. Work production is increased 1.5 times and the number of errors is reduce by 1/4.

PSYCHOLOGICAL RELIEF ROOMS

These are used in industry and could be used on spaceships. The effect is the creation of the illusion of being in nature. This is achieved by using large slides depicting scenes from nature, it has been shown to be effective for relieving visual fatigue and nervous emotional loads. To provide this, there is light-projection, sound-producing and odor-generating apparats.

Slides are shown with illustrations. The illusion of being in nature is created. A sound of slow music and the signing of birds can be heard.

Pleasant music is turned on and a soft, soothing light is turned on the color wall panel. Music becomes bolder and a stimulating, arousing light is turned on the wall panel. At the end of the session the room lights are turned on and invigorating music sounds. Data shows that after these sessions the workers are in an improved state of mind; their work capacity, attention and reaction speed are improved; the overall state of the central nervous system is improved. This method of psychological relief can increase work productivity up to 17%, while at the same time reducing traumatism.

GENERAL REQUIREMENTS

-Light and color time-indicator:
--Can be used to reinforce habitual biorhythm
--Color can have psychophysiologic and aesthetic functions without negative psychopharmacologic qualities

-Colored light and music programs:
--To maintain an awareness of months and the change of seasons

Color Preferences:

Experiments indicate the following color preferences:

- Blue
- Red
- Green
- Violet
- Orange
- Yellow (yellow and yellow-green sometimes lead to negative emotions)

Warm tones (red, orange, yellow) stimulate the nervous system. Cool tones (blue, green, violet) soothe it. This should be taken into consideration in selecting the color scheme for the spaceship interior.

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Saturated colors are preferred in small areas; shades and tints in large areas.

Color having a high reflection is recommended for the ceiling (to reduce the contrast between the light source and its background).

-Color formulations should be in contrasting tones.
Examples:
--The interior living quarters should be in warm, sunny tones: light yellow, straw, orange, pale yellow, green
--In rest and recreation areas: warm, relaxing colors with a color contrasting trim
--For sleeping quarters: muted, cool color tones. (This will create a feeling o coziness and the impression of increased space.) (19004 p.p. I-108-I-III)

EFFECTS

Music helps preserve high work capacity.

Music can be used as a means of psychological support.

Experimental analysis has demonstrated that work capacity is highest when cheerful music is used.

A stimulated effect can be achieved by the unexpected mix of musical numbers. Programs should alternate between quiet and loud, fast and slow, major and minor keys. (19004 p. I-114)

II Technology

AIR-TO-GROUND COMMUNICATION

Psychological support. Special radio programs, music and messages for broadcast to crews. Two-Way Television and Family and Friends.

Each evening the latest news is transmitted to the crew.

CREW AND GROUND

"The hardest thing during a flight is keeping good relations going with the Ground and Among the crew."

There should be:

-Psychological compatibility among the crew and the ground

Communication operators should have some knowledge of psychology and know how to use it in practice.

-Observe the etiquette of voice communications
-Evenly distribute questions between the crew members
-Avoid statements with negative implications
-Allow crew members the longest time in voice communications (19004 II-9-II-11)

III Organization

Scheduling should take into account:

-Professional activities of the crew:
--Basic work:
---Operations making up the main content of the program
---Daily operations in communications
-Personal hygiene time
-Preparation and intake of food time
-Physical exercise time
-Time for other necessities

WORK DAY LENGTH

A properly planned work day with adequate rest breaks:

-Retains productivity
-Restores energy
-Maintains normal biorhythm

Results of investigations have shown that efficiency can change during work not only in the biorhythmological aspect, but under the influence of the work itself. "...work is the best cure for anxiety and depression." (19004 p. III-22)

DAILY REST BREAKS

The regime of work and rest must restore work capacity and should prevent fatigue:

- At the first signs of fatigue, short rest breaks are recommended
- The first three to five minutes of rest are the most important in restoring work capacity

The advantage of short breaks is that during a short rest a work posture is maintained and so is the attention to work. Long breaks may lead to a reduction in the amount and quality of work performed. (19004 p. III-25)

LEISURE TIME

- Two-way television (which provides "meetings" with family, friends, scientists, artists, athletes)
- Video cassettes (of films, concerts and cartoons. This is assembled with consideration for the preferences of the crew)
- Self-education
- Listening to music (very important)

Leisure activities which do not require a lot of space and equipment should be strongly considered.

(19004 p.p. III-28,29)

Experience has shown that telecommunications are effective in maintaining the crew's emotional and work tone.

(19004 p. III-31)

Productivity is maintained by adhering to a regime of :

- Work
- Rest
- Nourishment

The main biological rhythm is diurnal rhythm of wakefulness and sleep, which protects the brain cells against exhaustion and insures normal activity. It is difficult for a person to get use to an inverted daily rhythm. Biological rhythm is a conditioned reflex.

Seasonal rhythms are inherent in people. (19004 p. III-42)

SEX ROLES

"In planning for the observation of fine color images--twilight phenomena, the colors of Earth's horizon--they had taken into consideration the ±women's eye for things.' At the same time the female pilot's experience in identifying local reference points can also prove valuable."

"...the Soviets believe there is a psychological advantage to having a woman as part of the space crew." (19004 p. III-79)

PSYCHOLOGICAL TRAINING

- -Training programs prepare crew members for stresses other than a crisis:
  - --Isolation
  - --Boredom
  - --Confinement
- -Training includes:
  - --Personality factors
  - --Group compatibility
  - --Psychological requirements made on any given activity
- -Individual psychological characteristics are taken into account:
  - --Human characteristics under conditions of space flight make it clear that training cannot be standard and stereotyped (19004 p.p. III-97-98)
  - --Individual psychological-emotional training is devised to train in methods of self-control and self-regulation of functions.
- -The ability to disassociate from a situation at the necessary moment:
  - --Preserves working capacity

--Necessary for psychological readiness for conscious action

"There is no scientifically founded and effective program of psychological training of the crew. The coordination of the crew as a group takes place at the level of common sense. In most cases, coordinated and friendly space crews are selected, which rules out the possibility of serious conflict in flight."

IV. Personality Systems

VOICE STRESS ANALYSIS

Verbal expression can give information about the psychophysiological state.

Speech reflects personality characteristics by the methods of:

- -Lexicon-grammatical analysis
- -Psychoacoustical analysis
- -Semantic analysis

MEASUREMENT

Speech should be measured by a specially trained group of experts.

Experts should have the confidence of the crew.

Technical devices are being used successfully to analyze.

When analyzing speech, experts should be attuned to changes in:

- -Style
- -Content
- -Intonation (19004 p.p. IV-19-20)

ISOLATION

Results of Isolation:

Studies have shown that the likely consequences of isolation are:

- -Emotional neurotic reactions to the absence of feedback
- -Post-isolation hypomanic syndrome
- -Phenomena of "catathymic negativism" (refusing an activity that does not conform with the emotional tone or effect)
- -General disorders
- -Sleep disorders
- -Psychological stress:
  - --Some specialists feel that the cause of psychological stress in human interrelationships under conditions of isolation can be such factors as:
    - ---Exhaustion
    - ---Information exhaustability

All of these are caused by both biological and social prerequisites.

The above results of isolation are based on studies that were done in an isolation chamber, which reproduced the psychological distinctions of a space flight. However, analysis of early flights has failed to demonstrate any noticeable psychological disturbances. According to this analysis of early flights, it was found that people can adapt well and work efficiently for a long period of time in a isolated state.

Isolation Tests:

Many isolation tests have established that behavior depends on:

- -Correctness of the advance hypotheses
- -Perfection of probablistic prediction

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-Correct evaluation of the external environment
-Self evaluation (19004 p. IV-33)

EXPECTED ATTITUDES

-Self control:

-Positive disposition

-Tolerance and patience

-Educated:
--The ability to react correctly
--Being able to find the correct solution to any situation in order to make it possible to continue working together successfully (19004 p. IV-36)

PSYCHOLOGICAL SELECTION

Psychological criteria include:

-Low anxiety level
-Emotionally well-balanced
-Extroversive personality
-A high level of intellectual and perceptive abilities
-High resistance to long-standing mental work
-Steady, voluntary attention
-Good attention separability and changeability
-Memory
-Capacity to control one's own reactions.

Psychological tests are done for establishing:

-Perception
-Intellectual abilities
-Psychomotor efficiency
-Personality traits
-Physiological indices of emotional reactivity (19004 p. IV-48)

Selection procedures

ROLES

The spaceship commander must have a good knowledge of all the technical equipment in the spacecraft, including the numerous engines and life support equipment.

An experiment has to be divided into elementary parts so that a person who has very little preflight experience in dealing with the object of study can perform is successfully. Scientific-research work, observations, analysis of obtained data, and the huge mass of information is highly intellectual. It is not a role of just observation and control. It also requires that the person be and active participant in case of technical failure.

Candidates who have a desire for permanent activity and who find rest in periods of switching from on kind of activity to another are preferred. (19004 p. IV-5)

View of Human Problems to be Addressed for Long-duration Space Flights

Space flight is an experiment; undoubtedly man's most successful, but essentially experimental all the same. Knowledge of man's response to space flight stresses is limited. (19005 p. 1136)

Clinical Medical Care:

The longer the duration, the more pressing is the need for an onboard diagnostic and treatment capability. Partly to this end, an integrated medical/behavioral laboratory measurement system, known by the acronym IMBLMS, is being developed.

For very-long-duration missions, it may be best for one crewmember to be physician. In short, he can distinguish between trivial procedural variations and serious ones that might create a bias in results. He will, in the course of the mission, be alert for signs of changes which may not have been expected and recognize patterns of response.

Psychological Fitness

Now that it is clear that he human organism can withstand the rigors of space flight, attention must properly turn from man as an organism to man as a psychological entity. We still know very little about the effects of the space environmental complex on personality and psychic well-being. These aspects of the human could prove to be the factors which limit the

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duration of space flight if they do not now receive the attention required. (19005 p. 1141)

Isolation, Estrangement, and Privacy:

If anything, man is over-stimulated by the numerous tasks he must perform and the unique visual experiences of his new view of the cosmos. The "silence of the void" is replaced by the sound of machinery which makes the spacecraft cabin at least as noisy as any typical office and sometimes noisier. Audiovisual monitoring prevents man from being isolated in the strict sense, even to the point of denying him modicum of privacy. If isolation is at all a problem in space it is an isolation that might better be termed estrangement. It is only natural for one to feel very much alone over a quarter of a million miles form all that is familiar. This response on the part of space crews was expected and, as early as the gemini 7 mission, efforts were made to combat the potentially demoralizing effects this estrangement might produce by supplying crewmen with news of events on earth and arranging for them to talk with their families. These steps should be continued in future space flight missions, with all possible efforts being made to ensure that personal communications can be conducted privately.

The issue of private or privileged communications arises also in connection with discussions between space crews and physicians monitoring their flight. It is essential that these communications be as private across the void of space as they are in an earth-based physician's office. While it is critical that telecommunications between earth-based monitoring stations and space vehicles be maintained, it is still possible to afford space crews a certain degree of privacy.

Where the need for one crewmember to remain private from another is concerned, earth-based studies have indicated that a feeling of privacy is not necessarily predicted on the provision of a specific amount of physical space. The subjects who participated in the NASA sponsored 90-day manned test of a regenerative life support system were confined to a chamber which provided only 90 square feet of floor space per man, yet the crew indicated that their privacy needs had been satisfied. They came to view privacy as the ability to separate one's self from other, if not in a physical sense, then in a psychological sense. Privacy was thought to be satisfied when all four men were located in the same area but were engaged in individual activities which did not require interaction.

Crew Roles: Roles must be strictly defined. The assignation of specific roles has been a feature of past space flight missions and will be a feature of future ones.

Crew Composition: Crew composition is as important as crew structure. For long-duration mission, crews will have to be even more carefully selected than they are now. It will be necessary to be psychologically and physiologically selective and, once adequate techniques have identified the most suitable individuals, to train those selected in psychodynamics so that they will better understand what they will face in long term space flight.

Psychological selectivity in training will be even more important when crews are no longer composed of highly motivated, robust test pilots, but include scientists and other civilian personnel. (19005 p. 1142)

Mixed crews must be seriously considered. The issue of mixing of sexes in space crews in the future may not be the delicate one it has been traditionally expected to be. The population from which astronauts will be drawn in future years will more than likely have spent their years in university training, studying and working in mixed groups and living in sexually unsegregated dormitories.

The Space Cabin Environment: Several aspects of the space cabin environment are particularly relevant to the psychic state to the inhabitant.

Early space flights and, particularly, long-term ground-based studies, have also shown that food becomes a critical morale building or degrading factor in isolated microsocieties. Personal hygiene maintenance and body waste elimination provisions, which have received far too little

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emphasis in the past, could become a major problem area for very-long-term missions unless they are at least considered in to play a serious role in habitability. The problems of defecation in space must be dealt with directly and without a trace of embarrassment.

While technological problems of a more pressing nature and economic issues dictated that the area of spacecraft decor would receive little or no attention in past and near future mission, for longer term missions this element of the environment must receive higher priority.

Sleeping Accommodations: Many space crewmen have experienced difficulty sleeping in space. In several cases, during both U.S. and Soviet mission,s sleeping medications have been prescribed. While lack of sleep or the taking of sleeping medications for short periods of time is acceptable during relatively brief missions, these will be unacceptable conditions for long-term occupants of spacecraft. To insure that more restful sleep is obtained, special seeping quarters will be provided. Each individual is provided with an isolated sleep area. Partitions and curtains insure privacy and a sleep restraint which hangs on the wall provides a space "bed." (19005 p.p. 1143-1144)

Missions to date have been extremely active with experimental tasks. As missions become longer with the possibility of increased leisure time, the astronauts will undoubtedly place leisure time activity higher on their preference lists. (19005 p. 1144)

Areas that have not posed problems thus far because mission durations have been short and crews have been very active may well pose problems on longer duration flights. In the future, efforts must be exerted towards selecting and training crews in the psychological sphere, for long-duration space flight imposes many different types of stresses than those encountered in the flight durations thus far. Waste management and body hygiene provisions for all mission have been, archaic. Such conditions cannot be tolerated any longer, particularly as we look to long-duration flights.

Man can be supported for long-duration space flight if we exert our energies to learn what is happening in that environment and then to define the responsible mechanisms. Once mechanisms are clearly understood, the proper countermeasures can be applied if necessary. We can gain this information and support man on a journey to the planets. (19005 p.p. 1145-1146) The US should take a good, long look at this to determine what changes could benefit our crews.

The Soviets have done a lot of study on human behaviors, and the US has to catch up in these regards. NASA has to ret moving or we may just have to settle for second best, and years behind of our competition in long missions to our neighboring planets.

I hope this can be accomplished in our life time so the results can be studied at length. The US Space program is a must, and we have to be competitive to survive.

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J

Chapter 20 Space Sickness

By: Scott Kimber

20.1 Definition of Topic

This chapter examines the issue of space motion sickness and how it might be studied in the variable gravity facility. Space sickness symptoms much resemble earth motion sickness.(20002) Space motion sickness is a neurophysiological problem resulting from conflicting signals sent by the otoliths (balancing organs in the inner ear), the eyes, and muscular sensors.(20009) These symptoms range from stomach awareness to repeated vomitting. Symptoms also include pallor and sweating.

Space sickness has been a recurring problem in the history of the space program. While this syndrome appears to decline in 3 to 5 days, in some cases the degree of illness has hindered work capacity and disrupted the scheduling of important acativities.

20.2 Background Information

The mechanisms responsible for balance and orientation are affected by the absence of gravity. The symptoms... are usually short-lived but can be dangerous. They include not only nausea (NASA officials reportedly considered scrubbing the 1968 Appolo Mission to the moon, when, after leaving earth orbit Frank Borman started vomitting) but also an array of odd bodily perceptions. An astronaut climbing a ladder may have the unsettling feeling that he is descending head first, and a mere turn of the head may produce sensations of falling, floating, or spinning.(20008)

The reason is that the neurovestibular system, the basis of balance, involves not only the eyes and extremities but also the gravity-sensitive otolith organs. In the absence of gravity, a given head motion still produces the same visual sensation, of course, but it has radically different effects on the otoliths. The result is a conflict of messages. Like the cardiovascular system; however, the neurovestibular system soon adjusts.(20008)

While adjusting to weightlessness, a number of astronauts had been afflicted by motion sickness. Although the 19 Americans, who had flown in Mercury and Gemini, had been immune to the poorly understood malady, almost half of the Soviet astronauts, flying in the slightly larger Vostok and Voskhod spacecraft, had suffered from it. With the start of Apollo, the Americans lost their immunity, 9 of 29 astronauts had motion sickness in that program, with nausea and vomitting persisting in some cases for several days. Because the problem was occurring in the larger vehicles, some doctors think the increased freedom of movement -

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particularily of the head- brought on the malady. It had been a pleasant surprise; therefore, when the first SKYLAB crew remained free from motion sickness. Conrad cautioned against undue optimism during a post-flight press conference, predicting that future astronauts could "experience some form of ... motion disturbance that may ... take more than a few seconds to get used to."(20003)

His warning was borne out less than an hour after the launch of the second crew, when pilot Jack Lousma complained of nausea. A capsule of scopolamine-dextroamphetamine, a medicine that blocks the nerve endings to the stomach, provided some relief, and he managed to eat lumch. The illness returned in greater intesnsity that afternoon as the crew began activating the workshops. By 6 p.m., all three men were experiencing motion sickness.(20003)

They showed no improvement the next morning, breakfast went half-eaten. At 8:30 a.m., Bean reported, "Although we're moving around getting thins done, we're not doing them as rapidly as we'd like to." At lunchtime, the crew had no appetite and the commander requested a break so that they could "get in the bunk and just stay still for awhile." He also asked Houston to consider giving them the next day off. Mission Control agreed to the mid afternoon rest, but the crew had to spend most of the time trying to resolve an electrical problem in the spacecraft. That evening the astronauts had fallen nearly a full day behind schedule; NASA officials postponed a planned EVA for at least one day.(20003)

After the flight, he (Bean) would attribute much of the sickness on the first to the first week's hectic pace. "While we were doing activation ... the whole thing was hustle all the time ... half of the problem we had (in) adapting to motion sickness was by the fact that we were not eating on time, we were not getting to bed on time, and we were not exercising."(20003)

The last crew of SKYLAB began its mission with little troubles, the docking gear was a hastle again, it took 8 hours to dock the command module with it. With that done, the crew was out of touch with Houston for 41 minutes between Bermuda and Carnarvon, Australia, so they started straightening up the command module, stowing away the gear used during rendezvous and docking. First, however, Carr and scientist-pilot, Edward G. Gibson, took their antinausea pills. Pilot William R. Pogue had already attended to that, but too late. A few minutes before ground contact was established, he asked Gibson to hand him a vomit bag. Gibson complied, and as he and Carr went ahead with their chores, Pogue said, "I think I'm going to go slow for a few minutes." It was not enough; weightlessness had done its work, and Pogue vomitted, not very much, but he was quite nauseated. Houston came back on the communication circuit just before 6 p.m. and reiterated the physician's warning about entering the workshop. Before launch, Carr had requested a change of plan to allow them to begin activating the workshop that

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evening, but flight planners saw no advantage in that. Carr agreed to wait until the next day.(20003)

20.4 Proposed Mission Requirements

The whole mission of the space sickness study is find out the effects of space sickness on the human body. Questions need to be answered about it's affects. The basic one: What exactly causes space sickness? Also, Can it be prevented? Will there even be space sickness at 0.1G? Can it be treated? Will you get sick all over again if the facility has more than one gravity level? If so how long will it take to get acustumed to the changeing gravity levels? Is it true that the more freedom of head movement the greater the risk of getting sick? Is it possible to train and /or test poeple on the ground to see if they'll get sick? Will it affect experiments?

The mission must answer these questions with some degree of accuracy in predicting or preventing space sickness.

20.5 Proposed Method of Meeting Mission Requirements

Prevention. There are no proven ways to prevent someone from getting sick. One way that has been tried with limited success is drugs. The pilot on SKYLAB 3 took anti-motion sickness preparation but vomitted anyway. However, the drugs must be taken well before the symptoms occur. The drug numbs the nerve endings of the stomach elevating stomach awareness. Autonomic response control is a technique that uses biofeedback and acquired autonomic response control to prevent sickness. It is the learned control os symptom supression. By controlling heart rate, respiration rate, and blood pressure, one can diminish and/or prevent one's space sickness. Currently, it is not known if groung training will prevent space sickness at all.

The symptoms of space sickness range from stomach awareness to profuse vomitting, therefore recognition of space sickness may pose a problem to identify. Vertigo and spatial disorientation are also involved in motion sickness. The feelings of tumbling and spinning are caused by vertigo and spatial disorientation. More research is needed in order to understand and identify the symptoms of space sickness; however, with the current technology and the known symptoms, it is possible to treat the symptoms after the fact. That is not what isdesired, the goal is to scientifically predetermine who will get sick and prevent it. Until an extensive study is done, it is not currently possible to determine this. A study of this size may take decades and millions of dollars to accomplish. For such an apparent minor physical discomfort that seems to be cured by time, NASA will not allocate money for this study.

Treatment should be composed of drugs and rest, as said earlier, some of the SKYLAB astronauts felt better if they lied still. Current drugs can only prolong the sickness. A program should be worked out using moderate amounts of drugs and rest by using current drugs at the time and updating them periodically.

Recovery does not require the crew member to leave his/her position, only in extenuating circumstances. Recovery may however allow the relaxation of ones duties until his/her condition improves.

Computer and/or computer programs will be required to monitor the crew members. If space and technology allow, the computer will warn of immenent illness, recognize the type of illness, diagnose a cure, and proved a continuing status of the crew member for as long as the crew member has an illness. This status report should not be limited to space sick patients. It is understood that a computer of this magnitude will cost hundreds of millions of dollars and will more than likely not be based in space. A computer such as this, if made, should be based on the ground and made available to other public and private sectors and be used as a data base.

20.6 Proposed Alternatives to Meet Mission Requirements

The alternatives are rather limited, without doing research into the subject the only other way to deal with the problem of space sickness is the old fashioned way, go into it blindly. Go up and resort to the conventional way of treating space sickness with a vomit bag. With the variable gravity facility it would be possible to use the tiolet, providing suitible gravity or splash resistancy.

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21 BONE LOSS

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(4/29/'87)

21.1 Definition of Topic

There are many different physiological problems which occur during space travel including: space sickness, unusual heart activity, muscle loss, red blood cell loss, white blood cell activity, and bone loss. This chapter deals with one of the more serious of these complications, bone loss. It will deal more specifically with the loss of calcium from bones, how to measure the loss of calcium, and what may be done to limit the loss.

21.2 Background Information

The body of a healthy human being consists of 206 bones differing in a wide range of sizes but are basically the same in content. Human bones are composed of organic and mineral components, containing 65-70% inorganic crystals and 30-35% organic matrix of osteoid. Collagen, which is the protein that forms the main constituent of the bones, accounts for 39% of the osteoid (21005, p. 378). Two-thirds of bone tissue is calcium and phosphorus, while the remaining is a form of gelatin. (This paper will only pertain to the calcium content of bones).

Vitamin D is responsible for calcium homeostasis (21005,

p. 1.). Vitamin D is a group of ten fat-souble vitamins, but research is mainly concerned with D2 and D3. Vitamin D3 forms in the skin when exposed to sunlight and is found most concentrated in fish-liver oils. This chapter will next examine the effects of space travel on bones.

Bone structure is usually easily maintained on Earth with four hours of walking or standing per day, but even when these normal activities are carried out in long term zero gravity space travel the bones are affected greatly. This could be for various reasons. Bone dimineralization could be a result of changes in activity of osteoblasts, bone-forming cells; ostoeclasts, cells in bone marrow which absorb bony tissue; or a combination of both. Another hypothesis is they lose a piezoelectric dynamic process, a procedure that will stimulate stressed bones to produce calcium, while others believe that a deficiency of vitamin D may be the culprit. The lack of vitamin D causes a disease called rickets. Vitamin D deficient bones appear more porous and result in less organic matrix. A fluid redistribution that occurs in low gravity could also cause a malfunction of a calcium regulator.

Testing done preflight, during the flight, and postflight are often compared to bed-rest patients on Earth and the first is always found to be more serious. Immediately during the first day of the Skylab mission calcium started to appear in the urine at above normal levels (21007, p. 1117). For the Skylab expeditions, diet was controlled and recorded for 21 days prior to, during the length of the mission(28, 59, or 84 days), and finally for 18 days after the return to Earth. If a certain mineral requirement was not fulfilled because the food was not completely consumed, the astronauts then had to take suppliments for that mineral the following day (21007, p. 1117).

During the 84 day mission, urinary calcium excretion increased while fecal calcium decreased for the first ten days (21009, p. 5). It did not appear that the change in urinary calcium would level off as it continued to increase from day to day (21007, p. 1115). One positive observation showed that approximately 30 days into the cummulative Skylab data the quantity of calcium in the urine plateaued approximately 100% above preflight levels and remained here for the remainder of the flight, but fecal calcium loss continued to increase after the initial few days. During the Skylab mission, the average amount of calcium lost per crewmember was 25 grams (21007, p. 1117). On an average day, a normal human loses 100-200 milligrams through urine (21005, p. 353).

The Russian Salyut program, also has done bone dimineralization testing. Bones were found to lose calcium at .5% of total body calcium per month with some bones losing as much as 5% per month. Covering a six month period, the average loss was calculated at 14% with one cosmonaut losing 19% of the total body calcium (21006, p. 160). The loss of calcium occurring in weightlessness is mainly in bones which are weight-bearing, such as the legs, feet, and mostly the trabecular cord (21004, p. 197).

Postflight data will be analyzed next. The majority of the calcium does return over an extended time on Earth, but some effects of extended travel are believed to be

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OF POOR QUALITY

irreversible. The amount of calcium excreted postflight dropped below preflight levels while fecal samples remained above levels of preflight for Skylab crewmembers. It appears that .5% of total body skeleton and possibly 5% in critical bone areas is lost for each 90 days in space (21002, p. 497).

This chapter has thus far looked at to what degree calcium has been lost on previous long term spaceflight. The aspect of exercising, which is thought to be one thing that can reduce the loss of calcium along with maintianing muscle strength, will be examined next. Any exercise (21011, p. 656) usually only stimulates increased development of the system that is most stressed. Muscle exercises like weightlifting are interrelated to calcium loss since increasing the reactive loads of muscles on bones helps inhibit bone dimineralization. Thus it is necessary to find exercises that are of good quality, stressing muscles and bones, rather than a large quantity of time.

Although all exercise machines are different, there are only three forms (21011, p. 657) of resistance exercise: 1) isometric--exercise where the subject strains against an immovable resistance, 2) isotonic--exercise there the subject move his limbs against a constant resistance, and 3) isokinetic--where the person works against a resistance of a seemingly constant rate. The third one is the only one where the subject can exert total force over the entire range of motion. This is supposedly the most efficent muscle strength exercise. Isokinetic exercise increases strength just as well as weightlifting, but rarely causes muscle discomfort which can occur during weightlifting.

Running (21011, p. 656) was thought to provide adequate musculeskeletal stress along with cardiovascular conditioning, but then was discovered to be less effective than a high resistance exercise, such as weightlifting, in maintaining muscle strength. Running also does not prevent bones from becoming porous like once believed (21011, p. 660). Rather, increased muscle mass has shown to increase bone mass.

Drugs (21011, p. 661) have also been shown to induce bone growth. The most effective appear to be anabolic steroids, such as nandrolone. They have been shown to reduce bone loss, but will not cause bony abnormalities. The steroids will take affect only when increasing muscle strength and thus must be used with exercise.

It appears that in gravity between zero and one G the loss of calcium surely would be less than that in total weightlessness. Although complete recovery after one's return to Earth seems possible, as seen with tests done with animals.

In such test chicks and mice were exposed to continual cetrifugation 4 and 5 gravities and stimulated bone growth occurred (21007, p. 161).

21.3 Proposed Mission Requirements

To determine the calcium loss at various gravities in the enviromental conditions of space. To analyze the degree of calcium loss a certain amount of testing must be done on board. Taking urine and fecal samples daily, along with recording the food the spacefarers actually consume. Procedures which could reduce the calcium loss in long-term space flight include increasing the intake of vitamin D and exercise equiment which would add stress to the bones.

21.4 Proposed Method of Meeting Mission Requirements

A) Preventing Calcium Loss

Provide Vitamin D into the system using a larger window or more windows. A strict diet should be kept and whenever certain necessary foods are not completely consumed supplimental vitamins will be taken. Exercise equipment such as a Jumper machine should be used during prolonged space travel simultaneously with anabolic steroids.

B) Monitoring Bone Diminerализation

An excretion sample method should be used to determine the loss of calcium in both the urine and fecal. These samples should be analyzed right on the station.

21.4.1 Discussion of Proposed Method

A) Preventing Calcium Loss

Considering the larger window area, this would help in terms of psychological reasons since windows have been shown to reduce stress between crew members on previous missions. They provide for recreational activities. A window in the sleeping area could provide for that area to be more personal and relaxing. A negative aspect is that they take from valuable wall space for other equipment and instruments.

Looking at exercise equipment, since exercise equipment that is efficient time wise is desired, isokinetic appears to be the best. The Jumper (21011, p. 658) made by Isokinetic Sales Inc. is one such machine. It is effective, needs only a few adjustments between exercises, and has less discomfort than isotonic devices. The speed of exercise can easily be changed with a knob. Subjects should always start with the harder repetitions and work their way down for greatest efficiency. Incentive is also provided by the speed indicator. Exercising on such a machine can reduce exercise time to as low as 30 minutes per day with better results than the 1.5 hours to 2.5 hours daily that had been performed on previous Skylab and Salyut missions.

Anabolic steroids (21011, p. 661), when used with an exercise program, increase muscle strength, which in turn helps hold the muscles to the bones.

B) Monitoring Bone Dimineralization

The procedure for analyzing urine samples entails collecting and pooling urine samples on a daily basis for a set period of time preflight, during the mission, and postflight. A sample, approximately 50 ml of urine, is taken every 24 hours and frozen. For testing fecal matter, samples should be taken as often as possible and freeze-dried.

Both urine and fecal experiments can be conducted on board. Testing should be done on weekly basis and then the samples could be disposed of instead of having to store them for months on board before the samples could be sent back to Earth.

Bone density measurements should be taken at least preflight and postflight along with testing for bone dimineralization.

21.4.2 Weight Estimate of Proposed Method

The Jumper system at current prototype weighs approximately 170 pounds, but using aluminum pieces, instead of the steel now used, could reduce the structure to around 100 pounds. Dimensions are 137 cm X 122 cm X 61 cm, not including the bench which would have to be added for upper body exercises (21011, p. 659)

21.5 Alternate Methods of Meeting Mission Requirements

A) Preventing Calcium Loss

One alternative method of getting vitamin D into the body is to put a immitation source of sunlight onto the station, such as a sunbed or sunlamps. Using sunbeds on the facility would probably take up too much of the needed space. Sunlamps on the other hand would take up less space and could be stored much easier with mainly the same benefits of obtaining sunlight as the sunbeds.

A treadmill is a piece of equipment which has been used on several previous expedition. As previously noted in 21.2, running on treadmills does not provide enough stress on the bones to help during space travel. Treadmills do provide high resistance which improves leg strength (21011, p. 657).

Another suggestion is a garment called the Chibis which creates a partial vacuum around the legs and hips. The Chibis (21006, p. 161) briefly reverses the effects of weightlessness such as fluid distribution and also approximates mormal gravity-bound circulation patterns.

B) Monitoring Bone Dimineralization

An alternative method to the excretion analysis is taking x-rays of the heel of the foot. This method is not very accurate, telling only if calcium is being reintegrated and mineral loss.

Urine and fecal samples could be collected and stored on board, being sent to Earth when the shuttle came up to resupply the facility. This would result in large amounts of samples being stored for months when it could be tested right on board.

21.6 Discussion of Unresolved Issues

Several questions still remain unanswered. If there is a region where calcium loss seems to plateau--where is it? Testing should be done in the VGF at gravities such as .25 G, .50 G, and .67 G. These values should provide an initial good overview of bone dimineralization. If one of these gravity levels appears to have reduced calcium loss, then continued testing shoud be done around that gravity level.

What are the weights of the testing equipment, freezer, and the device to freeze-dry fecal samples?

What specific exercises should be carried out and for how long?

21.7 Summary

This chapter has discussed the serious problem of bone loss with extended space travel. There does not appear to be a region where calcium loss plateaux. It has been observed how calcium loss can be prevented and the monitoring of bone dimineralization. Providing vitamin D for the body with windows of simulated sunlight, regulating crew diets, and using anabolic steroids with an exercise program can help in preventing calcium loss. Experiments with urine and fecal samples along with measuring bone density should be done to determine how much calcium is actually being lost. Using discussed suggestions hopefully a gravity level where calcium loss is at its minimum will be discovered to be used for future space expeditions.

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CHAPTER 22   Muscle Atrophy In Space
Luc R. Butzon
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22.1 Definition of Topic

Muscle atrophy is a progressive degeneration and loss of function of muscle tissue. Signs of which are wasting or shrinking of the muscle tissue and loss of muscle bulk.

22.2 Background Information

The physical bodily changes form prolonged exposure to weightlessness is the most pressing problem in future long term manned space flight and space habitation. In this report we will concentrate on methods of monitoring and preventing muscle atrophy and deconditioning of the heart along with other muscles due to prolonged exposure to zero gravity.

The musculoskeletal changes that occur in space are an adaptation to an environment of reduced skeletal loads. When one first attempts a task, large numbers of muscle units are activated. As skill improves, there is a progressively more successful repression of unneeded contractions. Muscle units which are not used begin almost immediately to lose strength at a rate of about 18% per week, and degenerate irreversibly within four months (22028). Weightlessness produces a number of structural and functional changes in skeletal muscles. These changes are most pronounced in the antigravity muscles such as the gastrocnemius and the muscles of the back and neck. Leg muscle strength decreases, particularly in the extensors.

Deconditioning of the cardiovascular system occurs early in weightlessness but tends to stabilize after the 5th week of flight. Cardiovascular conditioning becomes a medical problem after a space traveller is subjected to acceleration forces encountered during reentry or upon return to the constant 1g stress on earth. Depending on duration and amount of exercise performed in flight, return to pre-flight values of cardiovascular function could be as great as one month (22026).

In Cosmos - 1129 experiments of atrophy of rat muscles with different functions was performed. Changes in muscle weight and extent and velocity of contractions were observed and tested. It was found that the muscles, depending on their function, behave in different ways under conditions of weightlessness. The greatest degree of atrophy occurs in the mainly slow-fibre containing soleus muscle. atrophy is much slighter in the Extensor Digitorum Longus (EDL) muscle which contains fast fibres. Readaptation is not identical in muscles with different functions. EDL muscle regains its weight in a few days of training, whereas that of the soleus muscle takes many weeks.

It was also found that muscle weight returns to normal earlier than the value of maximum tension (22003).

Possible methods of reducing muscle atrophy and cardiovascular deconditioning may be by achieving a high level of conditioning immediately prior to flight and provide a regime in the capsule which conserves pre-flight fitness (22003). There are three basic forms of resistive exercises:

a. In isometric exercise the subject strains against an immovable resistance.
b. In isotonic exercise the subject moves his limbs his limbs against a resistance which is constant.
c. In isokinetic exercise the subject works against a resistance which moves at a relatively constant rate. The subject exerts maximal force over his entire range of motion.

22.2 Proposed Mission Requirements

1. Monitoring atrophy of skeletal muscles
2. Investigate possible counter-measures to prevent or forestall muscle atrophy

22.3 Proposed Methods of Meeting Mission Requirements

1. Muscle atrophy can be monitored through:
   a. anthropometric measurements of the neck, chest, biceps, forearm, waist, thigh, and calf and also percent of body fat
   b. strength index test to find any changes in muscle strength
   c. physical examination such as urine analysis, blood pressure, and pulse rate
2. Counter measures
   a. spin up space craft to 1g
   b. isokinetic exercises to strengthen and condition muscles

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22.4 Discussion of Proposed Methods

Anthropometric measurements can be done very simply by a tape measure. This measurement is determined by measuring the circumference of muscle bulk areas [redacted] which were discussed previously.

Skinfold method is best suited for measuring percent body fat. The skinfold caliper is lightweight, portable, and easy to use. The caliper is placed on a vertical plane of the skin at various positions of the body. Readings are then taken after application of spring pressure.

Measurements for strength index may be determined by using a cable tensiometer. This instrument measures the pulling force of a muscle during a static or isometric contraction in which there is essentially no change in the muscle external length. This instrument can record forces at all points in the range of motion of a specific joint. These tests are excellent isolating and evaluating strength changes in specific muscles weakened.

All measurements should be obtained by the same individual in order to reduce interindividual variation. These measuring devices are consistent in their period.

Blood pressure can be determined by a sphygmomanometer. Pulse and heart rate can be monitored during exercise and rest by connecting the subject to an Electrocardiogram. Urine analysis should focus on the loss of metabolites such as Nitrogen, Potassium, Creatinine, and amino acids for they are associated with muscle breakdown.

Isokinetic exercise devices were found to have the greatest strength improvement over isotonic devices and isometric exercises. Greatest efficiency load should be maximal at the beginning of exercise, to recruit the maximum number of muscle fibers. As the subject fatigues, the load is gradually reduced and the number of repetitions increased. This type of "descending pyramid" loading, maximizing nerve stimulation and muscle stress, is easily adapted to the isokinetic device (22002). A thirty minute intense exercise regime three times per week should suffice to maintain a moderate degree of fitness.

22.42 Weight Estimate of Proposed Method

Weight of an available system in current prototype is approximately 45 kg with overall dimensions of 137 cm x 122cm x 81 cm (22022).

22.5 Alternate Methods of Meeting Mission Requirements

One gravity of artificial gravity along with a light physical fitness program will prevent muscle atrophy.

A faster means of propelling space craft to objective, therefore greatly decreasing elapsed time of flight to a safe amount of time, could alleviate muscle atrophy.

22.6 Discussion of Unresolved Issues

Does partial gravity prevent or decrease atrophy of muscles?

Can crew members perform useful work immediately after landing in 1/6g or 1/2g after prolonged exposure to zero gravity?

Anabolic agents and electrical stimulation of muscles should be investigated.

22.7 Summary

It is believed that an adequate exercise program consisting of cardiovascular and strength conditioning along with an effective diet will prevent many of the adverse effects of atrophy. However, these are subject to speculation. Complete information can only be obtained through critical, long term observations in space. At this point we lack adequate understanding of the atrophy process in humans and therefore, lack effective counter measures.

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Charpter 23

SEXUAL NEEDS

Christine Ensberg, Kay Pues, Mike Spletto, Robert Volden

.1 Definition of Topic

An individual's sexual needs and the crew's private quarters are two humanistic aspects that must be considered in building a variable gravity facility. This, then, touches on the issues of birth control, living and sleeping area design, and need for privacy.

.2 Questions

Sexual needs

1. What type of contraceptives will be used? What are the side effects on Earth? In space, zero-g, and variable gravity?
2. Who's responsible for birth control?
3. Should one birth control method be used? A combination? Which method, or combination of methods, has the fewest side effects (such as fluid, or weight, gain)?
4. Religious objections to contraceptives?
5. Individual medical reactions, problems, or complications from contraceptive use?

Bedrooms

1. How will the need for personal space affect room size?
2. Does personal space requirements vary with culture?
3. Does the required living volume vary with the gravity level?
4. How many beds per compartment? How much storage space per person and of what type?
5. What type of furniture and beds should be used?
6. Are there any restrictions on personal items used for decoration (weight, material, etc)?
7. How do you decide who gets the single and double bedrooms?
8. Should conventional beds be used? Offer several types?
9. Will sleeping people have trouble staying on the bed in low gravity?

.6 Design Requirements

Sexual needs

More than one form of birth control will be used. Both men and women will be responsible for birth control.

Bedrooms

The bedroom will be each crewperson's private space. Both double (10' x 12') and single (8' x 12') rooms will be available. Furniture and beds will be made from a light-weight, perhaps inflatable, material and will allow easy furniture rearranging.

.7 Expanded Design Requirements

Following is a list of possible contraceptives:

FEMALE (6304, p. 60)

1. The Pill: Measured doses of progestin and estrogen that inhibit the release

of eggs from the ovary.

2. Implants: Tiny rods in the upper arm that release progestin to inhibit ovulation and implantation.

3. Sterilization: Fallopian tubes are permanently tied or cut, preventing an egg's passage from the ovary to the uterus.

4. IUD: Changes the uterus lining, somehow preventing eggs from implanting. Some contain copper, others emit progestin.

5. Vaginal Ring: Rubber ring with a hormone core. Worn in the vagina, where hormones are absorbed that inhibit ovulation.

6. Sponge: Polyurethane, spermicide releasing sponge that is placed over the cervix to prevent sperm from entering the uterus.

7. Diaphragm: Rubber dome that covers the cervix, used with spermicides (creams, jellies, foams).

8. Injections: Antipregnancy vaccines that elicit antibodies to hormones and sperm, and progestin shots that prevent ovulation.

MALE (6304, p. 61)

1. LHRH Analogues: Brain chemical that halts release of all sex hormones, to turn off libido and sperm syntheses. Must be taken nasally.

2. Gossypol: Derivative of cottonseed oil taken in pill form. Checks sperm synthesis but does not disrupt hormone production.

3. Inhibin: A hormone produced by the testes. Stops pituitary from releasing FSH (follicle-stimulating hormone) so that sperm production is suppressed.

4. Sterilization: The spermatic ducts are permanently cut or cauterized so that sperm cannot pass through.

5. Condom: A thin rubber sheath that keeps ejaculated sperm contained. Also is an effective barrier against sexually transmitted diseases.

Bedrooms

The bedrooms will be regarded as the crewperson's personal space (6307, p. 12). Both double and single bedrooms will be available (6306). The beds and furniture will be made from a lightweight, perhaps inflatable, material (6306) and will allow easy furniture rearranging (6308, p. 77).

.4 Areas Needing Further Research

Sexual needs

1. The human psychological need for sex.
2. Additional information on contraceptives. Especially in the areas of cost, effectiveness in preventing pregnancy, and possible side effects.

Bedrooms

1. More habitability needs. Especially considering differences in territorality, need for privacy, and storage of personal items.
2. Information on materials for furniture and beds.
3. Bedroom design.
4. Assessment of volume requirements, especially at varying gravity levels.

.5 Obtaining Data and Information

Sexual Needs

1. Psychological need for sex
   Interviews with professors in the Psychology Dept.
   Reports on related studies.
2. Information on contraceptives
   Contraceptive studies on earth.
   Look into speculation on how contraceptives will work in space.

Bedrooms

1. Habitability needs
   Research by David C. Nagel, Chief of Aerospace Research Center (6302, p. 2050)
   Volumetric assessment (how much one gets in space)
   Design and decor (ex. high tech vs. naturalistic)--contact architecture school at NDSU?
   Consideration of privacy needs (which would encourage intimacy)
   Sociology or behavior research-esp. in territorality needs

2. Material and Designs
   Research by NASA
   Architects and architectural design research

.8 Solutions

CONTRACEPTIVES

If men and women plan on living in the vgf, it will be necessary to use some method of birth control. The choice of birth control method will be left up to the individuals involved. In order for individuals to make an informed choice, we must determine the most effective form(s) of contraception in space.

Since "sex is a nonissue for NASA right now" (6302, p. 2020), we can only speculate which methods will be effective in space. Since this subject hasn't been studied in zero-g, or variable gravity, we can only rely on a contraceptive's effectiveness as established in Earth's one gravity environment.

The first, best, and probably least popular method, is sterilization (6304, p. 59). This method is possible for both men and women. Although this method is almost ideal (near 100% effectiveness), crewmembers should not be forced into it. Women should consider using the Pill, or receiving implants, as an alternative form of contraception. The Pill is 98% effective. Implants, good for up to 5 years, are nearly as reliable as sterilization (6304, p. 61). Men have a more limited choice of alternate contraceptive methods which include condoms and inhibin. Inhibin is still being tested, but if it proves safe and successful it must be considered a viable alternative (6304, p. 85).

More than one form of birth control method should be used because we cannot predict how a particular contraceptive will work in space. Frank Sulzman, Ph.d., Acting Chief of NASA's Space Medicine Branch explains that "Drugs are taken by the body differently when in space than they are on earth," a likely result of the body's redistribution of fluids while in the weightless state (6302, p. 2020). Although the vgf won't be completely weightless, it will still be less than one gravity. For this reason, we cannot be sure the contraceptives will work, or be as effective, as they are on Earth. Therefore, a combination of methods should be used to provide some overlap in case one method fails. In the future, after adequate testing, using a combination of proven contraceptives may provide an effectiveness in preventing pregnancy equal to that of sterilization.

BEDROOMS

The most crucial rights on the vgf will relate to property. Namely the possession of personal items and a private living space (6307, p. 12). Privacy is an essential need of individuals in isolated and confined settings (6308, p. 76). Studies of two people in an isolated area reveal that they learn very quickly about each's mundane qualities. At this time they begin running out of things to say to each other. Because of this, they avoid each other, interacting less and less even though they feel more isolated and lonely. Social discussions decrease and individuals become more possessive of their space, which is simply a means of establishing their privacy and maintaining social distance from the other (6308, p. 76). The requirements for maintaining a person's privacy will depend on the number of people, the habitat's size, and each individual's personality (6305, p. 87).

First of all, we must determine the minimum volume of space necessary to fulfill a person's basic needs. A look at the distances a person needs for comfort and variables which affect those distances will help make a judgement. Some of the variables which affect a comfortable setting are the relationship of the interactants, their sex, and the setting within which the interaction is taking place (6301, pp. 50-1). Experiments show that both men and women choose closer, rather than further, distances for comfort. Eyeball to eyeball distances of six feet is the limit of comfort (6301, pp. 50-51). The personal space required among acquaintances is less than that among strangers. More space is preferred in stressful or anxiety producing situations (6301, p. 75). All these aspects, plus the room's function, must be considered when deciding on a room size.

Any interior will be perceived from utilitarian and emotional viewpoints (6305, p. III. 87). On long term flights it's important to keep the rooms looking and feeling as close as possible to those on Earth (6305, p. III. 87). The rooms "should be made as changeable [flexible] as possible" (6308, p. 77). Furniture and beds should be easily moved, instead of built in, allowing each crewmember to arrange the room to suit his own tastes. Another reason for this versatility is the positive reaction during a changing environment experiment. "[Change] removes monotony and uniformity of environmental factors" (6305, p. III. 87).

We recommend double and single size bedrooms for maximum comfort (6306). The double room may be used by sexual partners, whether married or living together. The double room will also have a sliding door or divider that will make it into two single rooms (6306) just in case sexual partners need privacy from each other. Beds will be inflatable and made of a lightweight material. This will increase space and floorplan diversity when needed (6306).

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CHAPTER 24

ENVIRONMENTAL STRESS

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Doug Kelley

April 28, 1987

24.1 DEFINITION OF TOPIC

Environmental factors can contribute to psychological stress in the restricted environment of the variable gravity research facility. Several physical environmental factors are examined and parameters for them in the variable gravity research facility proposed.

24.2 BACKGROUND INFORMATION

Stress factors such as physiological stress and socio/psychological stress, as well as psychosomatic complaints that apply in both forms of stress, all play great determinants in the success of crew missions (24002, p. 27,28).

The space station's environment, that of close confinement, isolation, color and texture, noise and smell, as well as lighting are very important, consciously and unconsciously. Past conclusions indicate that these working conditions, along with the importance of work, are critical to performance (24001, p.25).

It is assumed when evaluating the history of past crews in space, that environmental aspects should be taken into consideration (possibly to a higher degree), when working to improve productivity and research in space. With the current activity of constructing the variable gravity research facility, and in reducing stress, consideration of environmental aspects may deserve attention (24005, p.16).

24.3 PROPOSED MISSION REQUIREMENTS

The mission requirements in regards to environmental psychological stress is to alleviate as many stress producing factors as possible. We should promote an aesthetically and acoustically comfortable environment, in reference to the five senses by:

A. Sight

1) Maintaining adjustable lighting to coincide with the performance of the crew and a pleasing atmosphere.

2) Providing for a variety of decor and color to reduce boredom.

3) Equipping the station with two-way television for visual ground communications.

4) Window placement should be utilized for visual diversion and facility expansion.

B. Sound

1) Improving crew activity with music.

2) Reducing noise perimeters depending upon the tasks of the mission and the activity of the crew.

C. Touch

1) Enabling the crew to nurture or care for plant and/or animals.

D. Taste

1) Providing an array of foods for a variety in scheduled meals.

E. Smell

1) Leaving natural smells in food and sundries for a comfortable atmosphere.

By a combination of these means, we hope to provide a way to alleviate stress produced by these environmental factors.

24.4 PROPOSED METHOD OF MEETING MISSION REQUIREMENTS

To meet requirements in reducing stress, and addressing the five senses, we must incorporate what we know about each area, realizing that they overlap each other with their effects on crew members.

In dealing with sight, maintaining adjustable lighting to coincide with the performance of the crew is very beneficial. Guidelines to the use of reducing stress are as follows:

1) Reflected lighting and the brightness or dimness of illumination may cause tense stress factors and eye fatigue. The use of filters to produce natural light may reduce stress due to intense or dull illumination.

2) The use of contrast in lighting, and reflection for walls, ceilings, floors, and equipment may be used to pinpoint sources for work, or give a feeling of comfort to the crew, thus reducing tension (24004, p.I-102).

3) Due to the lack of atmospheric absorption in space and high brightness level with abrupt contrasts (glare), individual light controls may help to give crew members a "choice" as to how

intense the illumination they would like for work or rest and recreation (24004, p.I-100).

4) An example of how to vary the light controls for the crew members is to equip the lights with lux (level of illumination) variations. These would vary from routine work levels of 200-500, to fine detail or high precision work which use up to 1000 lux (24004, p.I-104).

With the implementation of light controls to give a variety of choices for the crew, a variety of decor and color will also help to reduce stress caused by boredom, fatigue and reduction in psychophysiological tone. These stress factors lead to:

1) Loss in job interest and reduction in overall personal interests.

2) Physical anesthetization

3) Altered behavior (24004, p.I-108).

To combat these stress factors, color and music help to alleviate these tensions and increase the motion stability of the crew. The requirements for color preferences are:

-Blue

-Green

-Red

-Violet

-Orange

-Yellow (may cause negative emotions in some cases) (24004, p.I-110).

To implement color, warm tones (red, orange, and yellow) stimulate the nervous system and therefore could be used in areas that need excitment to add motivation and productivity. An example would be in high working areas.

Cool tones (blue, green, violet) soothe the nervous system and should be used in rest and relaxation areas, such as the sleeping units, to calm and give the feeling of coolness and the impression of increased space. This would greatly help to alleviate stress patterns in the crews behavior (24004, p.I-111).

Interior living quarters could use contrasting tones to set the mood for seasonal rhythms. Examples for seasonal changes with color may be:

Winter: Neutral coloration with a contrast of light and dark and an absence of any brightly accented colors.

Spring: Clear, colorful, bright colors used.

Summer: Color masses with three color combinations predominating.

Fall: Color schemes vary, depending on the home origin of the crew members (24004, p.I-112).

Seasonal rhythms help to bring about a feeling of change that is needed to combat monotony and stress that may decrease productivity (24004, p.I-112).

A vary important aspect in the visual sense is air to ground communication. The use of two-way television for emotional support from the crew, and especially the family, is a great stress reducer and seems very important (24004, p.I-11). A method may be considered:

1) Implementing proper television cameras for discussion with ground crew and family/friends. As the mission length increases,

duration of communications is necessary,(24004, p.II-9) therefore it should be considered for stress relief. As time aboard increases, so must the time spent on two-way communication with family and friends.

Windows are extremely important in that they lessen the feeling of confinement and reduce stress caused by being in confined conditions. The construction of these windows would be beneficial to have in as many areas as possible, especially in personal quarters, to aid in diversion of confinement (24005, p.16).

Along with the incorporation of color, two-way television and window views to reduce stress factors, music plays a great role in psychological relief of tension.

The use of music stimulates work capacity, and effects physical and psychological health, therefore alleviating stress symptoms. Some of the effects of music may be used as follows:

1) Work capacity is highest when cheerful music is used, stimulating the nervous system and heart. Stress can be reduced, and music being the outlet, to "let off steam", or relax, depending of the tempo and orchestration used (24004, p.I-114).

2) Slow and deliberate, long duration music could be piped into sleeping quarters to combat insomnia and stress caused from lack of sleep. This would be according to personal preference.

Noise levels and vibroacoustics play a major role in the stress factor. High and even low to medium intensity noise, all lead to:

-Irritability

-Sleep disorders

-Headaches

-Premature aging (24004, p.I-146).

With factors like these, stress develops very easily and the need for restricted noise levels becomes apparent to reduce tensions. Some examples:

1) When looking for solutions to noise levels, music, again becomes an important factor. It can be brought in at intervals, (into the sound system) or on individual head sets, depending on the duty performed or rest situations.

2) The use of sound-insulating and sound-absorbing materials, as well as general reduction in the level of noise to optimal values would alleviate stress and discomfort. These feelings must be addressed, as they are not always conscious, and can cause great pressures on the crew the longer they continue unmonitored. High intensity noise causes alterations in nerve cells that affect the psychological state of humans. This can be detrimental to the success of the program and therefore noise levels should be monitored and reduced. (24004, p.I-146,148).

The reduction of stress producing factors in lighting and noise levels are important, as is enabling the crew to have the choice of proper temperature. The presence of too much heat within the station produces irritability and discomfort. The main problem within the station tends to be keeping the temperature down, due to the intense heating system. Hot and cold air are mixed through the process of fans to produce the right temperature for productivity (24004, p.I-153). Combinations of air and wall temperature, humidity, and general circulation should be mixed so that the members of the facility do not become overheated (24006, p.20).

Plants may be used to produce some of the "comforts" of home, which help to minimize the stress of being in a foreign environment. Plants become important in that they produce life on board and also reduce pressure by giving crew members an aesthetic beauty of life on earth (24003, p.9).

In regards to the last of the senses, taste and smell, food, and the smell of food play important roles in improving the psyche of the crew members. Psychological stresses were reported to have been eased by fruit juice, for example, perhaps because of how it was in its natural form (24004, p.I-126). Some solutions for food and scent variations may be:

1) By offering more natural food forms for treats or special events, the psychological conditions of the members may be boosted.

2) Improvement of the food palitability of rehydrated foods should help to lessen the frustration of the crew members with the preparation and taste of the rehydrated foods (24006, p.27).

3) By allowing perfumes from shaving lotions and deodorants to remain in these sundries, small levels of stress may be reduced because of the enjoyment they receive from the "smells" of earth (24003, p.9).

4) By allowing the use of air fresheners and the natural scents, and keeping general circulation from becoming stagnant with fan and vent methods, (due to lack of gravity induced air

convection) reduction of "machine" smells may be accomplished .

24.4.1 DISCUSSION OF PROPOSED METHODS

The advantages to producing an aesthetically and acoustically comfortable psychological environment for the crew members prove to be important and numerous. All seem to lead to a more productive crew.

1) By producing for a variable environment, the crew members can be more productive. There is less concentration on the "little" things that normally produce stress. (i.e. High intensity sound) (24004, p.I-146).

2) There is more room for decisions and choices, in decor and color choice, food choice, or the options of lighting and temperature to provide for changes in the environment.

3) There are less problems with crew compatibility when environmental stress factors are reduced, thus providing more time for positive performance and interaction in regard to working and projects.

4) There are better sleep patterns within the crew members, when stress due to the environment is reduced, therefore providing for more productivity.

5) By providing as many earth-related environmental items as possible, the unconscious factors that produce pressures in the surroundings will be alleviated, thus reducing physiological difficulties (i.e. The alleviation of nerve cell disruption due to high intensity noise levels, or insomnia) (24004, p.I-146).

6)Personal relations, via two-way television communications, with people outside the facility may help to maintain cordial relations within it (24007, p.58).

7) Communications help to reduce the stress of confinement by exposing the crew members to a different environment through television communication means.

8) The abundance of windows would help to produce facility expansion and positive diversion of the crew members free time.

The disadvantages of providing for a stress-reducing, comfortable psychological environment are mainly engineer oriented.

1) The cost of designing a station that provides for the five senses completely, would be very great. Lighting, paint, and unprocessed food in particular, would be controversial due to their weight and space consumption aboard the station. They would be costly to carry and implement their use throughout the stay in space.

2) Providing the right mix of acoustics and lighting, as well as food or personal items would be difficult for pleasing each member of the crew.

3) Engineering problems may develop if the variety of decor were to be implemented, as providing many decorative options, and their weight characteristics, may take up space that could be used for essential equipment and experiments.

4) The excess use of window space may interfere with the equipment and experiments again, due to the space consumption.

5) News from home could possibly be anxiety-provoking rather than anxiety-reducing. Family problems or the "Dear John" communications may not be tremendously uplifting (24007, p.58).

6) There may be other disadvantages that develop during the flight due to maintenance of aesthetic and acoustic equipment and education of the crew about the systems.

24.4.2 WEIGHT ESTIMATE OF PROPOSED METHOD

The weight characteristics of the lighting, sound, and food which contribute to environmental satisfaction have varied weight estimates, due to the degree in which the new ideas could be implemented.

24.5 ALTERNATE METHODS OF MEETING MISSION REQUIREMENTS

24.5.1 The first alternative to producing a complete comfortable environment for the reduction of stress may be, due to costs, implementing only the most important factors of stress reduction.

By conducting tests to determine which of the senses; sight, sound, taste and smell, or touch, would be most affected by the mission requirements and would be beneficial in appropriating the engineering aspects more towords one area, thus reducing the cost of equipping the station.

24.5.2 Another alternative of providing for all of the aesthetics may be to conduct research for super lightweight materials to use for acoustics systems and "furniture", or lighting.

24.5.3 A third alternative to implementing a complete system for improving environmental stress may be to educate the members of the crew on how to control stress and recognize it in other people. Meditation instruction and "yoga" could be an example of a means to alleviate stress (environmental or personal).

24.6 DISCUSSION OF UNRESOLVED ISSUES

The unresolved issues and questions of environmental stress reducers tend to be based on the disadvantages of the process.

1) If we could produce this type of environment, where can we find the funds to implement it into the station?

A solution to this may be to go to congress with it, and try to get more federal funds allocated to the program.

With the allocation of as much money as necessary, the majority of factors, even small ones such as what personal belongings, could be taken, (weight and money) could be solved.

24.7 SUMMARY

I think that it can be concluded, due to the benefits of providing the elements for a stable environment, psychologically, that more consideration, engineering, and money should be allocated to improving the environment of the station to reduce stress.

According to Dr. B.J. Bluth, we can replicate past mistakes if we do not spend money on "behavioral stuff" and the "soft" science in a hard science program (24003, p.8). "People are not infinitely adaptable. They have limits. The human factor becomes more and more important as time increases" (24002, p.29).

Perhaps in this sense we can take into consideration the importance of implementing a productive and changeable environment. Psychological stress and tension may be reduced. We may find that progress and productivity with experiments and research proceed much faster and more effectively. Isn't that what the space station concept is about? Progress.

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CHAPTER 25

PSYCHOLOGICAL TESTING

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25.1 Definition of Topic

For the Variable Gravity Facility it was decided to limit psychological tests to those of value, to determine in flight, the psychological health of the crew. These tests should have demonstrated predictive value on earth and if possible in space as well. The tests should be designed not to interfere with the performance of the crew and to insure their comfort and safety.

25.2 Background Information and Assumptions

The history of studies of men in confined, isolated, and stressful environments points out many potential problem areas for spaceflight. While none of these environments replicates the conditions aboard an orbiting spacecraft, there are many parallels. Some problems seen in these environments are replicated in the US and USSR experience.

Early research suggested sensory deprivation effects such as hyperexcitability and in severe cases hallucinations or illusory stimulation (25001). These phenomenon have been reported in radar scope operators and isolation tank subjects after only two or three hours.

Social effects of isolation are illustrated from the Korean conflict "brain washing" phenomenon. These techniques later became known to US behavior modification practitioners and social scientists as milieu control and lack of consensual validation and are defined as manipulation of all communication within the environment and removal of the consensual validation we are all accustomed to with society at large (25001).

The Korean captors used the POW's environment to manipulate their behavior to a surprising degree. Limiting environmental rewards resulted in increasing significance of those made available, and highlights the importance of feedback on human performance as a reward for continued performance.

It should be noted that the general literature on antarctic adaptability has also witnessed increased suggestability (25002). This has occurred when the crew assumed that outside ability to resupply was indicative of group performance, and had a pronounced effect on morale. Actually, the weather was the deciding factor for resupply missions.

Space crews have also demonstrated a certain sensitivity to communications with the ground on long duration flights (25022). Which, as a major social activity of the crew, has a great importance for morale, and control reasons. Also noted was the issue of lack of assertiveness, almost causing the loss of a cosmonaut on an unscheduled

EVA, and the parallel lack of assertiveness that caused an airline disaster (25003).

While generalizing from these situations to long term space flight is possible, the history of psychological tests to predict behavior for spaceflight is dismal. As Bluth (25023, p.26) quoted Vinograde (25004), "Neither emotional stability, social compatibility, nor overall performance could be accurately predicted by clinical evaluation, personality scales, opinion survey items, or personal history."

This lack of predictive value is probably reflected in the dropping of psychological testing after the early US space program. Nevertheless performance loss noted in simulators, submarines, and the antarctic over long duration missions demand that we attempt to understand the relevant factors.

The general approach to predicting behavior must utilize experimental methodology and behavioral technology validated in countless animal studies and in behavior modification accomplishments with humans. This approach generally places a high priority on the physical and social environment of the spacecraft. Joseph Brady and Henry Emiurion found in a John Hopkins Hospital isolation study that rewards were the best motivators and that cooperation was better than competition at fostering performance (25005). Also noted was NASA experts' preferences for neurometric measures, like those used by the Air Force, which measure how well a person functions in a simulated environment rather than on disfunctions.

Psychological abnormalities do crop up in spaceflight however. Depression is reportedly common in the Soviet experience (25005) and in the Antarctic and submarine crews (25006). However, there are ways of limiting its effects with training, work, and recreation activities.

There are also means of assessing performance in flight. The Soviets prefer physiological measures, such as pulse rate, skin resistance, and electroencephalograms, to predict stress levels (25007).

Performance assessment in the US has used single and multiple tasks and 'synthetic work' to predict performance (25006). Simulators, however, remain the most realistic performance assessment tools in the space program with strong predictive ability. It was suggested that "computer graphics offer a flexible alternative to full scale modeling" (25006), and may have multiple uses on the VGF.

To maintain performance and morale the concept of meaningful work has relevance. Astronauts and others in isolated and confined environments have listed work as their most preferred activity (25010). Job satisfaction is acknowledged to stem from intrinsic and extrinsic aspects of work, satisfaction from the work itself versus the pay, and recognition as the external components (25006). Meaningful work emerges from confinement and space studies as having social or economic relevance. Substituting 'synthetic work' or computer games is not likely to provide for the needs of the crew on extended missions.

The intrinsic factors are linked to utilization of worker's skills in various activities that produce a visible piece of work and to significant goals that affect the physical or social well being of other people. Intrinsically motivating jobs should also provide autonomy or individual freedom, and provide some feedback on performance according to Hackman and Oldham (25008).

Extrinsic motivation could be increased though pay incentives with increasing mission length and by assuring news coverage and recognition at least within interested space groups. Perhaps, a weekly TV interview would prove beneficial for motivation for work and to help alleviate the isolated feeling expressed by many astronauts.

Furthermore, there are tests to match people's interests with those in occupations they find rewarding such as the Strong Cambell Interest Inventory (SCII) which could be validated for astronauts or for the type of work envisioned in confined, isolated, and stressful environments (25006).

25.3 Proposed Mission Requirements

1. Monitoring crew performance and psychological state to predict behavioral problems.
2. Applying behavioral techniques to reduce or eliminate problems which may endanger the crew or mission.

3. Develop and test theoretical models which appear to have value, in generalizing from lab to field studies on stress, isolation, and confinement.

25.4 Proposed Methods of Meeting Mission Requirements

The following tests were selected as having the greatest predictive value for assessing the morale and performance level of the VGF crew. These tests should also provide useful data for comparisons between past and future research in these areas.

PSYCHOLOGICAL, PHYSIOLOGICAL, AND PERFORMANCE TESTS

I. Sealab Tests are recommended due to similarity of the sealab environment to space flight (25011). They would also be of value because they provide a research base of previously validated instruments which could be extended to space. They would also provide a weight savings.

A. Predive Data (Preflight for the VGF)

1. Socieometric ratings (status, cohesiveness)
2. Mood Checklist (most important for depression)
3. Personal history booklet
4. Attitude inventory
5. Adjective checklist
6. Allport Vernon Lindzey Scale of Values
7. Strong vocational interest inventory (parallels to astronauts)
8. FIRO-B social relations orientation

B. During Dive (Flight) - measures mostly nonintrusive

1. Order of Arising TV
2. Meal recording TV (adjustment, interaction)
3. Location record TV (Gregariousness)
4. Night watch record TV
5. Outside telephone calls, etc. official records (adjustment)
6. Diving log (performance objective measure) could substitute work time ratios on VGF
7. Mood adjective checklist "best self report measure" (25011)

C. Post dive (flight) measures

1. Questionnaire
    a. Adequacy of habitat
    b. Use of leisure time
    c. Desirable characteristics of crewmates
    d. Mood adjective checklist
2. Debrief interview (mostly anecdotal data) illustrative and supplemental data
3. Leader ratings of team members performance correlation with dive (work) records

II. Performance tests

A. Discrete Task Techniques tests one aspect of performance. They have the advantage of low weight and cost but the validity is untested (25006).

B. Multiple Task Performance battery of synthetic work requires identical work stations, validity unknown (25006,25012).

C. Full Scale Flight Simulation offers the best apparent validity, however, computer graphics offers a flexible alternative to full scale simulation without hardware development and weight penalties (25016). An important function, such as docking ability or reentry attitude, could perhaps be simulated via computer graphics including various malfunction modes.

D. The Embedded Secondary Task methods are recommended for in-flight assessment (25014,25019).

E. Educational Performance at selected study tasks could be monitored and compared to earth or space station home study programs. Study time could also be incorporated into the following area for motivational assessment.

F. Work Time ratios for each crew member can be calculated through observations on TV and monitoring devices. The ratio is obtained by dividing the total daily time spent working (or studying) by the total hours available for work. Typical values on earth are 0.5. Skylab results were higher before space sickness interfered (25006,25015).

G. Air Force Tests for performance assessment. The Tri-Service performance assessment battery is nearing completion and is suggested for pre and post shuttle flights (25014). The feasibility for in-flight tests for the space station needs to be addressed. This test battery may be available for the VGF time frame.

III. Physiological Tests to predict psychological state. (Stress levels) Soviet preference to performance tests which can be compensated for.

A. Pulse rate, objective measure of emotional stress.

B. EEG (electroencephalogram)

1. Beta activity signals increase in emotionality, stress, and alarm.

2. Alpha rhythm predominates individuals characterized by activity, absence of stress, and confidence.

C. Skin resistance and respiration rate.

1. An increase in the later marks the transition from calm wakefulness to full alertness.

D. Analysis of acoustic characteristics of speech have been successful in estimating the degree of emotional stress and correlates with heart rate. Disassociation of these two measures yields a stress index independent of physical exertion (heart rate) (25007,25020,25021).

E. Intention Tremor can be measured in operator controlled equipment through strain gauges and microcomputers (25014,25016,25017).

TECHNIQUES FOR REDUCTION OF PSYCHOLOGICAL PROBLEMS

I. The importance of feedback on individual performance is emphasized, in isolated and confined environments. Brady and Emiurion found rewards more effective than punishment, and cooperation better than competition in such environments (25005) at fostering performance. The importance of consensual validation is emphasized by Bluth. The flow of conversation is probably vital in order to talk astronauts through a dangerous situation or one which they do not understand (25024).

II. Results from Sealab and other studies suggest greater external rewards (money and recognition) may be needed in later more routine spaceflights, to motivate astronauts (25011). Also intrinsic rewards can be increased though job design according to Hackman and Oldham (25008), jobs should:

   A. Provide various activities and skill levels.
   B. Have task identity or produce visible work.
   C. Provide significant benefits to physical, psychological, or social well being to other people.
   D. Provide autonomy or control.
   E. Provide feedback on progress.

III. Fear levels studied in parachute jumpers suggest that experienced jumpers who deal with their fear well beforehand are more relaxed just before a traumatic event (jump) than are inexperienced individuals (25006). This study suggests that a crew be advised of danger well before they need to deal with it, and stresses the value of experience in dealing with fear.

IV. Psychological Episodes or problems

A. Remote counselling requires two way TV and a secure communications or radio link. This was listed as a high priority item with the NASA working group on Research Opportunities in Human Behavior and Performance (25014). A computer therapist is a possibility.

B. Also of value are crew training in:

1. Behavior modification
2. Problem solving
3. Assertiveness training (25003)
4. Awareness training was reported as most valuable by a crew in an isolated and confined environment (25006,25018).
5. Hypnosis has had some success among submarine crews (25006).

C. Meditation and Exercise have had positive effects on individuals feelings and relaxation. Biofeedback is another way to accomplish this along with similar autogenic training.

D. Recreation

Studies on Soviet flights found films (horror movies) could relieve depression, common on long term flights, and that unexpected surprises played an important role.

25.4.1 Discussion of Proposed Method: Advantages and Disadvantages

Psychologists and psychological tests have historically been viewed with suspicion by astronauts in the US space program, probably due to their initial use as a screening device. Now that those test batteries have been dropped, due to their inability to predict performance, this may change. However, the use of self report measures and the like should probably be limited for this reason and for those listed by Radloff and Helmreich (25011). "Such test (of character) have proved too singularly ineffective in predicting performance and adjustment. Personality tests have also recently come under attack for reasons other than their demonstrated lack of validity" (25011, p. 194). Their recommendations for field studies, such as using a variety of collection methods, and being as unobtrusive as possible actually simplify data collection. By using records kept for other purposes and systematic observations, subjects are not influenced by researcher questions. Also noted was the use of real performance criteria with the project goals in mind, this will require some thought in the case of the VGF where secondary goals may be used.

Some observations from Sealab II were found to be of little use such as "activity level" which was related to nothing else. Also the "Daily Activity Checklist" was a self report form which for a number of reasons was of little use. These items could be useful in the VGF environment, however.

Pre and post flight tests are included for base line data and for comparison with data obtained during flight operations.

Performance tests are included as a "real" criteria of a long duration space mission of this sort, using computer graphics for testing and work periods simultaneously. However, the synthetic nature of this work should probably limit its use to testing purposes, not just for something to do. Actual work should be as meaningful as possible.

Work time ratios may be expanded to include study time, which could itself be analyzed to produce a grade on work quality, compared to the same home study or space station base line. Individual selection interest levels may make base line data collection difficult.

Discrete task tests, although having a low weight penalty suffer the same untested validity problems as multiple task tests (25006). This would not be a problem with the tri-service assessment and embedded secondary tasks (25014).

The Soviet physiological monitoring techniques may be useful as a backup check on stress levels, particularly the voice stress analysis. More intrusive measures, however, such as respiration and continual skin resistance hook-ups may be interpreted as a sort of lie detector by astronauts. As such, these intrusive devices may introduce more stress than they alleviate, by questioning astronauts integrity, unless they are used simultaneously for medical reasons.

The problem of generalizing from laboratory studies on stress and confinement lies with the ethics of imposing stress on subjects. Stress usually implies an element of danger and cannot be duplicated in the lab. The sealab research was one situation where stress was a very evident factor along with isolation and relatively confined conditions. As the authors stated, "Perhaps the closest parallels to life in sealab would be the experiences of astronauts in orbit...Communication was possible but physical return was impossible for the individual to achieve directly" (25011, p.5).

The authors go on to emphasize the cost versus reward relationship of hazardous environments. This theory illustrates a major problem of lab studies where costs are quite low. The rewards are usually also lower in the lab studies, compared to any new exploratory venture where rewards or recognition are quite high.

It is this ratio, costs to rewards, which the authors maintain if defined would provide a basis for going from lab to field studies. Environmental factors do work to keep the ratio somewhat proportionate from lab simulators to field environments. Use of the measure from sealab would help to quantify this relationship in either situation.

25.4.2 Weight Estimates of Proposed Method

EQUIPMENT FOR PSYCHOLOGICAL, PHYSIOLOGICAL, AND PERFORMANCE TESTS

I. Sealab II tests are primarily done through existing records and TV monitoring facilities which are assumed to exist, as they do on the shuttle. One hundred percent coverage of module is not necessary. Observers can be trained college and graduate students. The mood adjective checklist could be administered through normal personal computer means requiring a data and program disc per astronaut. Pre and post flight measures would not require any onboard equipment.

II. Performance tests could also use computer graphics for simulation in the cognitive area and probably for hand-eye coordination. However, gross motor movements involving body orientation would require specialized equipment. Reported difficulties in catching a ball after spaceflight may require including a tennis or Nerf ball, which could also be employed in gross movement tests and games. A joy stick with flight controls in simulator mode could test fine motor movement adequately. Additionally a data and program disc per person-mission would be required per test. Simulation tests assume 12 discs per person-mission.

Educational material would be entirely software estimated at ten floppy discs per person-mission, or material could be sent up electronically and recorded for later research use.

Work time ratios would be determined through ground based observations using existing monitoring equipment. Electronic stop watches are assumed to be universally available as wristwatch equipment for astronauts.

Air Force or Tri-service tests are assumed to employ computer simulation on existing general purpose equipment. Requirement: A program disc and a data disc per person-mission.

III. Physiological test equipment is assumed to use available medical equipment with the exception of the EEG machine. In this case the weight penalty if over ten pounds would probably not justify its inclusion. The most valuable stress test, voice acoustic analysis, could use existing voice channels and ground equipment, thus involves no weight penalty.

The weight of the Intention Tremor device is not known at this time, however, the use of existing computer equipment would limit the weight to strain gauge equipment which would probably be under three pounds. Additional floppy discs are assumed to be a data disc per person-mission.

EQUIPMENT FOR REDUCTION OF PSYCHOLOGICAL PROBLEMS

I. Feedback/ Earth communication: existing equipment

II. Money and Recognition would not add to the weight of the VGF. Work requirements would probably involve electrophoresis equipment which may or may not be similar to shuttle equipment. Other equipment not identifiable at this time will probably be included in the appropriate category as it evolves.

III. Fear alleviation techniques add nothing to the weight of the VGF.

IV. Remote counselling requires a secure radio or TV link for private space-ground communications. The weight penalty for this item could be minimized by placing only one CRT, camera and audio device in a sleeping area which would be unused much of the time. The system would have multiple uses as a sleep monitor, and entertainment/information read out. Space-earth security would require a computer algorithm on a disc. Educational materials, exercise equipment and recreation requirements are best handled in those respective sections.

25.5 Alternate Methods of Meeting Mission Requirements

PSYCHOLOGICAL AND PERFORMANCE TESTS

I. 25.5.1 Various methods of self reporting could be used to assess the psychological health of the crew rather than observations. These include attitude, emotional state, mood, personality assessment, and subjective work load (25014). These could replace nonintrusive measures to save on observational costs on earth, but reliability and validity are questionable and are given a low priority (25011). Any savings in observational cost would also probably be offset by increased astronaut time load which has cost much more.

II. Performance tests may not be necessary at all if confidence in earth observations is high enough. The following tests are ready to go at the present time, however, the anticipated Tri-Service test will probably be superior if time is available for its completion.

25.5.2 The Army Performance Assessment Battery (25014) is available at the time of this writing.

25.5.3 The Air Force Criterion Task Set (25014) is also available and probably is the best fit for astronauts.

III. Physiological tests for stress may be unnecessary, however, some backup is necessary to confirm any problem which might compromise astronaut safety.

25.5.4 Voice stress analysis is the most desirable alternative to other physiological tests. It is non-intrusive and has no weight penalty.

25.5.5 Heart rate data is currently available and can determine stress, but you cannot distinguish between physical and psychological stress with this measure alone, unless activity and environmental conditions are known.

TECHNIQUES FOR REDUCTION OF PSYCHOLOGICAL PROBLEMS

I. 25.5.6 Feedback on performance should be provided from the ground and is recommended due to impartial and significant nature.

25.5.7 Feedback could be internal from the team leader or commander but may cause internal conflicts. May save money on external support personnel.

25.5.8 Computer evaluations of performance could be useful for some standardized tasks and tests but not in novel situations. They would save money and avoid strife.

II. 25.5.9 External rewards would be easy to manipulate but may not be effective for people on long-term missions.

25.5.10 Internal job enhancement may prove impossible with some jobs but should work with most activities.

IV. 25.5.11 The only alternative to countermeasures to psychological problems would be to include an expert in the crew on the following techniques: group dynamics counselling, behavior modification, awareness training, and hypnosis in isolated and confined, stressful environments. Such a person has been found useful in the antarctic (25006). The penalty is the weight of that person and their suitability as a subject in a limited crew.

25.6 Discussion of Unresolved Issues

The biggest unresolved issue at this writing is the use of astronaut time aboard the VGF. We do not anticipate that all of the physiological and psychological tests envisioned will take any major fraction of a normal working day to perform.

Other useful work functions need to be identified. The suggested electrophoresis work needs to be quantified. Earth observations suitability on a rotating, orbiting craft need to be defined. The unique rotating configuration of the VGF may make 3-D images of earth possible on a routine basis and may prove useful for other earth observations.

Educational programs occupy substantial amounts of individuals' time on earth, often in relatively isolated and confined environments. Whether such programs will be applicable in space needs to be explored for long term missions.

Issues of confidentiality and privacy need to be addressed with regards to monitoring data and camera placement. Privacy needs of individual crew members need to be determined. Are individual sleeping areas sufficient?

The feasibility for in-flight tests for the Tri-Service performance assessment needs to be addressed. The space shuttle spacelab and the space station should offer opportunities to evaluate these and other recommended performance tests in space.

The Embedded Secondary Task also needs further development and should require "only trivial additions to procedures to be performed in simulation and spaceflight" (25014, p.48).

25.7 Summary

The mission length envisioned for the VGF and the anticipated Mars mission will place unprecedented demands on their respective crews. Isolation, confined, and stressful environment studies on earth suggest potential psychological and performance problems for long term spaceflight. Some of these problems have already been confirmed from actual space experience. For the safety and comfort of the crews, means must be developed to assess performance and predict and deal with problems in-flight.

Earth studies suggest better predictability of unobtrusive psychological assessment. Work performance is related to psychological well being, and meaningful work becomes an even more important component of it in a spacecraft environment. Physiological tests are also reliable predictors of psychological stress and can be unobtrusive and a part of medical regimens. Embedded performance tasks and standardized performance tests are available.

Predicting performance may become secondary to maintaining it and dealing with problems in-flight on long missions which cannot be terminated. The intrinsic and extrinsic rewards of space work can be optimized with careful design, and fear can also be dealt with beforehand. Crew training in assertiveness, behavior modification, and awareness can reduce problems in-flight, as can remote or computer counseling. Recreation and entertainment will become increasingly important on longer missions both to fill the time and to relieve stress and depression.

Research from Sealab II suggests a model for generalizing from lab to field studies which needs to be quantified. The VGF offers a unique opportunity in this regard. Simulators have given the best predictive value in assessing performance. A simulator or one-G facility would allow behavior and performance measures to be tested and refined, as well as other requirements and limitations to be determined. Group dynamics and space ground communication needs could also be addressed along with crew limitations. The eventual testing aboard a nearly identical VGF in space would establish validity of the various earth based measurement instruments.

A Walk/Talk through a spacecraft mock-up with management and planners as well as astronauts has proven useful in past space systems to identify unresolved issues and prioritize research (25014, p.49).

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